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Mayor's Office,
Baltimore.

March 23, 1901.

Mr. J. C. Rowell, Librarian,
University of California,
Berkeley, California.

Dear Sir:-

Yours of 18th instant is at hand, and has been referred to the City Librarian, with the request that he forward you a report and supplement of the Sewerage Commission.

Yours truly,

E. J. Ryan

Mayor's Secretary.

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SECOND REPORT

OF THE

Baltimore.

SEWERAGE COMMISSION

OF THE

CITY OF BALTIMORE,

CONSISTING OF

MENDES COHEN,

F. H. HAMBLETON,

E. L. BARTLETT.

APPOINTED BY JOINT RESOLUTION OF THE CITY COUNCIL
APPROVED 25TH MAY, 1893,

AND CONTINUED BY JOINT RESOLUTION APPROVED 18TH MARCH, 1898.

BALTIMORE,
1899.

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PRESS OF
J. W. BOND COMPANY,
BALTIMORE, MD.

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TABLE OF CONTENTS.

	Page.
Resolution of Instructions to the Commission	7
Pollution of Oysters	9
Characteristics of the Chesapeake Bay	10
Typhoid Infection	11
Alternative Plans	16
Special Systems of Sewage Purification	20
Agricultural Filtration on Anne Arundel Lands	23
Agricultural Filtration Combined with Special Treatment	24
Recommendations	26
Ways and Means	28
Proposed Sewerage Company	30
Concentration of all Sewer and Drain Construction	33
Selection of Plan	33
Conclusion	35
APPENDIX A.	
ELEMENTS INVOLVED IN REVISION OF COST	41
APPENDIX B.	
PROJECT D—AGRICULTURAL FILTRATION	43
First Installation for Low-Level Service	43
Completed Work	46
Estimates of Cost	49
APPENDIX C.	
PROJECT D-E—TREATMENT AT MASONVILLE	53
Estimates of Cost	56
APPENDIX D.	
PROJECT L—DILUTION	57
First Installation	57
Completed Work	59
Estimates of Cost	61
APPENDIX E.	
PROJECT L-M—DILUTION, COMBINED WITH SPECIAL TREATMENT	65
Estimates of Cost	65
APPENDIX F.	
REPORT OF MR. JAMES MANSERGH, C. E., ON THE BACTERIAL TREATMENT OF SEWAGE IN ENGLAND	67

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Page.

APPENDIX F—Continued.
PART I.—Facts and Results..... 68
Dibdin's Bacterial Filters..... 68
Cameron's Septic Tank—Exeter..... 75
" " " —Yeovil..... 80
Lowcock's Aerated Bacterial Filters..... 83
Ferozone-Polarite Process..... 86
Ducat's Aerating Bacterial Self-Acting Filter..... 90
PART II.—Criticisms..... 95
Dibdin's Bacterial Filters..... 95
Septic Tank Treatment..... 100
Lowcock's Aerated Bacterial Filter..... 102
Ferozone-Polarite Process..... 102
Ducat's Aerating Bacterial Self-Acting Filter..... 103
PART III.—Applicability of Bacterial Treatment to Baltimore..... 103
PROFESSOR G. SIMS WOODHEAD, F.R.S.E., ON BACTERIOLYTIC SEWAGE BEDS..... 105
Introduction..... 105
The Action of the Dibdin Filters..... 107
The Work of the Anaerobic and Aerobic Organisms..... 109
The Septic Tank Process..... 111
The Dibdin Filters when dealing with Septic Tank Effluent... 119
The Influence of Variations in the Flow of Sewage..... 121
General Conclusions..... 122
APPENDIX G.
WARING'S SYSTEM OF PURIFICATION OF SEWAGE BY BACTERIAL OXIDATION..... 125
APPENDIX H.
PENNSYLVANIA SANITATION COMPANY'S METHOD OF SEWAGE PURIFICATION..... 129
APPENDIX I.
SCOTT MONCRIEFF SYSTEM OF SEWAGE TREATMENT..... 133

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LIST OF PLATES.

		Facing Page.
I.	Map of Chesapeake Bay	10
II.	Topographical Map Showing Outfall Sewers	16
III.	Map Showing Interceptors, District Mains and Sewerage Districts for Agricultural Filtration—Project D	42
IV.	Profiles of Interceptors for Agricultural Filtration—Project D	46
V.	Profile of Eastern High-Level Interceptor for Treatment at Masonville—Project D-E	54
VI.	Map Showing Interceptors, District Mains and Sewerage Districts for Dilution—Project L	56
VII.	Profiles of Interceptors for Dilution—Project L	60
VIII.	Profile of Outfall Sewer for Dilution—Project L	64
IX.	Dibdin's System at Sutton	70
X.	Septic Tank Treatment at Exeter	74
XI.	Ducat's Self-Acting Filter Plan of Ferozone-Polarite Works at Chorley Lowcock's Aerated Bacterial Filter at Wolverhampton	86
XII.	Diagrams shewing Rotation in Delivery of Charges to Filter Beds under varying conditions	96
XIII.		98
XIV.	Waring's Bacterial Oxidation Process—Willow Grove Park	126

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REPORT

OF THE

SEWERAGE COMMISSION.

To the Honorable,

The Mayor and City Council of Baltimore:

The Sewerage Commission has the honor to submit a further report in accordance with the duty assigned to it under the following joint resolution:

"*Whereas*, It appears that the recommendation made by the Sewerage Commission in its report, dated September 20, 1897, that the disposal of the city's sewage be by discharge into the Chesapeake Bay, causes apprehension that the waters of the bay may be thereby polluted and the oyster interests be thus affected unfavorably;

"*Resolved by the Mayor and City Council of Baltimore*, That the Sewerage Commission be and it is hereby authorized and directed to make further investigation and report what is, in their judgment, the best alternative plan which, whilst proving effective in the disposal of the sewage, will serve to relieve all public apprehension of pollution to the waters of the Chesapeake Bay."

"Approved March 18, 1898."

"WM. T. MALSTER, *Mayor*."

As directed by this resolution, the Commission has reconsidered the recommendations of its report, submitted under date of September 20, 1897, and has carefully revised

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the estimates therein made. It finds no reason to abate its confidence in the conclusions and recommendations of that report, and reiterates its belief that the true and most economical method of disposal of the domestic sewage of the City of Baltimore is by discharge into the Chesapeake Bay at a distance from the western shore of from one to two miles, where, remote from any usable oyster beds, it will be diluted, diffused and oxidized by the enormous discharge of the Susquehanna River, and will be practically destroyed without causing offense anywhere along the shores of the bay and without affecting deleteriously either the oyster itself or the commercial interests concerned therewith.

The existing storm-water drains, freed from the pollution of domestic sewage and cess-pool overflows, will empty, as now, into Jones' Falls and the harbor, carrying nothing but street washings and leaving the basin free from most of the putrefying organic matter which is the great cause of its offensive condition now so generally and justly complained of.

The waters of the bay, which already dispose of the sewage from the larger towns and cities along the shores of the Susquehanna River and its tributaries, with population now aggregating upwards of 700,000, and also those of the Patuxent, Potomac, Rappahannock, York, James and Elizabeth Rivers, with a population now reaching 500,000, not mentioning those of less important tributaries on the eastern shore of the bay, will really receive, by reason of such discharge, little more than is already carried there, other than what will be due to the further growth of the city; for the present foulness of the Patapsco finds its way there sooner or later. The dredgings of our basin and Jones' Falls, loaded into scows, are now dumped there, and much, even of the night soil of the city, when removed and distributed upon farm lands along the shores of the Patapsco or its tributaries, soon reaches the bay through the action of rainfall.

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POLLUTION OF OYSTERS.

Whilst it has been very clearly established, as well in this country as in England and in France, that oysters exposed to sewage contamination may breed disease when eaten uncooked, yet so far as we have been able to ascertain, such effect has only been found where oysters have been planted in, or transplanted to, in-shore localities for development or fattening, or for convenience of storage near market, and have there been directly exposed to the sewage outfall of more or less populous districts. The only records of such effects which have reached us have been due to exposures within short distance of the outlet of pollution, and we have the expressed opinion of investigators against the probability of any such risk with increasing distance.*

Sir Richard Thorne Thorne, M.D., F.R.S., a high authority, says, speaking of layings, fattening beds or storage ponds round the English coast, "But as regards the majority of them any such polluting matter becomes mixed with so vast a bulk of water that it is difficult to see how the layings can be subjected to anything approaching substantial risk of deleterious influence."

Again—"So also the dilution of the sewage is * * * at times, indeed, so considerable that the chances of sewage contamination hardly call for notice."†

Dr. H. Timbrell Bulstrode says, speaking of the exposure of the Mumbles oysters on Swansea Bay, "The sewage of Swansea finds its way into Swansea Bay some three or four miles distant from the layings. The amount of dilution which Swansea sewage must undergo in crossing the bay, if as a matter of fact it can cross it, must needs be so great

*Report of Sewerage Commission, September 20, 1897, pp. 53 et seq.; also Report of Dr. G. S. Buchanan to the Local Government Board, (England and Wales,) February 19, 1898.

†Sir Richard Thorne Thorne, M.D., Report to the Local Government Board, (England and Wales,) on Oyster Culture in Relation to Disease, October, 1896, pp. ix., xiii.

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as to render a consideration of it in relation to the Mumbles oyster beds unnecessary."* .

Again, in speaking of the oyster fisheries of the River Medway, he says: "The oyster layings in the Medway are situated in positions quite remote from habitations, in fact in positions which are by land very difficult of access. * * * As regards these layings it must, I think, be held that they are largely protected by their position and the enormous volume of water in the Medway."

Further, the same investigator says: "Obviously it is possible to reduce to an absurdity the demand for absolute freedom of food supplies from such risks, and to regard, for instance, all articles of food exposed to the ordinary atmospheric conditions of towns as liable to specific contamination, more especially if regard be had to the somewhat cosmopolitan distribution of *bacillus coli*. As regards oysters it would not be difficult to argue that even the deep-sea oyster beds may, in theory, not be entirely free from risk of dangerous contamination."

CHARACTERISTICS OF THE CHESAPEAKE BAY.

The Chesapeake Bay, into which this Commission has proposed and still recommends to discharge the sewage of the city, amounting in the somewhat distant future to a maximum daily flow of 126 million gallons or 194 cubic feet per second, covers an area of some 2,500 square miles, exclusive of lateral estuaries, and has a total length of about 190 miles from the mouth of the Susquehanna River to the sea. The point recommended for the discharge of the sewage of Baltimore is distant about 30 miles from the head of the bay and is some 160 miles from the sea. It is designated on the accompanying map of the bay, Plate I, by the point marked K. The depth increases from the shores to a maximum in the channels of 75 feet at the upper end, and to 215 feet before the southern line of Maryland is reached.

*Report to the Local Government Board, October, 1896, pp. 55, 81, 82.

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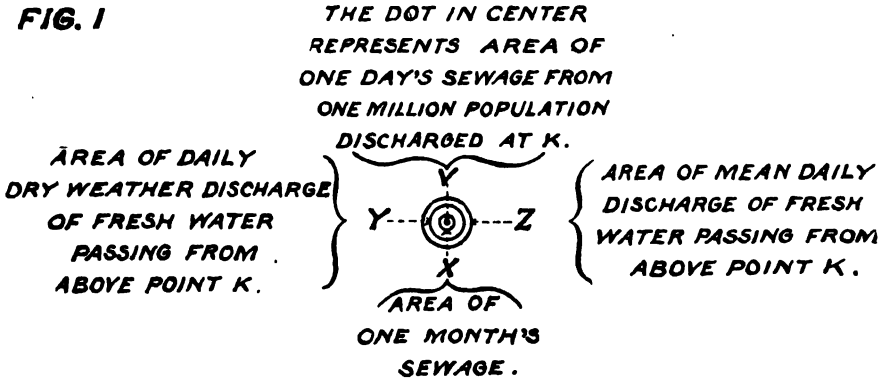
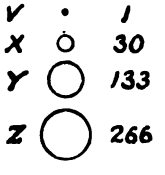
FIG. 1

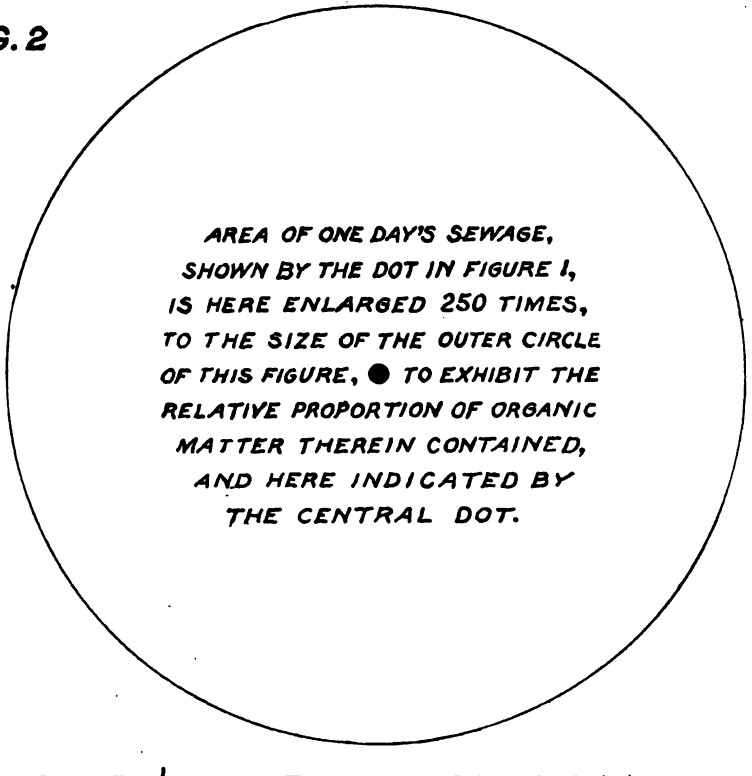

THE DOT IN CENTER REPRESENTS AREA OF ONE DAY'S SEWAGE FROM ONE MILLION POPULATION DISCHARGED AT K.
AREA OF DAILY DRY WEATHER DISCHARGE OF FRESH WATER PASSING FROM ABOVE POINT K.
V
Y
Z
X
AREA OF MEAN DAILY DISCHARGE OF FRESH WATER PASSING FROM ABOVE POINT K.
AREA OF ONE MONTH'S SEWAGE.

PROPORTIONATE AREAS WITH EQUAL DEPTH OF 20 FEET



SCALE $\frac{1}{800,000}$ OR SAME AS THAT OF PLATE I.

FIG. 2


AREA OF ONE DAY'S SEWAGE, SHOWN BY THE DOT IN FIGURE 1, IS HERE ENLARGED 250 TIMES, TO THE SIZE OF THE OUTER CIRCLE OF THIS FIGURE, ● TO EXHIBIT THE RELATIVE PROPORTION OF ORGANIC MATTER THEREIN CONTAINED, AND HERE INDICATED BY THE CENTRAL DOT.

SCALE $\frac{1}{3200}$; 250 TIMES THAT OF PLATE I.

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At its upper end it receives the outpour from the Susquehanna River, the dry weather flow of which has been variously estimated between 15,000 cubic feet and 35,000 cubic feet per second. Lower down there is added to its waters the discharge from innumerable tributaries, great and small, giving an additional volume of fresh water, which may be estimated at 41,000 cubic feet per second, mean dry-weather flow.

It may thus be seen that the Chesapeake Bay is not a stagnant pool without current adequate to protect and purify itself from defilement of any sort, nor a mere arm of the sea depending entirely for such purification on the agitation of its waters by the tides; but is in reality a great estuary with a tributary water-shed of some 71,000 square miles, receiving a constant accession of fresh water at an average rate throughout the year of approximately 132,000 cubic feet per second. Of this fresh water rather more than two-fifths is received at the upper end of the bay and above the point where it is proposed to discharge the sewage of Baltimore.

If to this volume of fresh water there be compared the output of sewage, which in the future may attain to as much as 194 cubic feet per second and of which less than one-thousandth part consists of organic matter, the ratio is found to be so small that the idea of contamination or defilement of the waters of the bay thereby seems to have slight foundation.

The diagrams, figures 1 and 2, show by inspection the relative volumes under consideration.

TYPHOID INFECTION.

It must, however, be borne in mind that it is not from the sewage itself that detriment to the oyster is apprehended. All fish life in the waters of the bay is dependent for its support upon the organic matter suspended in its waters. This it takes up, digests and assimilates. The alleged ground for apprehension is found in the possi-

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bility that the typhoid bacillus, discharged from the bowels of a patient in the city, may survive not only the long voyage through the sewers for some 15 miles to the deep waters of the bay, but, still living, may continue its voyage till it happens to strike an oyster bed, although there are now none within several miles of the proposed point of sewage outfall. If the bacillus is taken in by the mouth of an oyster, that probably ends its possibilty for evil; for we have authority for the statement that the typhoid bacillus does not develop and increase in the stomach or tissues of the oyster, but is digested by it, and soon disappears, leaving no trace.

The chance remains, however, that the bacillus may lodge *on* an oyster and not be taken into its stomach. This oyster may be dredged with thousands of others, and be conveyed to market. Here, instead of being "processed" by heat and packed in cans or otherwise for other and distant markets, it may happen to be eaten raw. Now comes the only chance of trouble. If this bacillus, still surviving all the knocking about it has had since it left its birth-place and habitat in a human intestine in Baltimore many days before, should happen to be caught on the oyster knife and delivered with the oyster to an individual, whose stomach is out of condition and only waiting to be attacked, then, and only then, we have the catastrophe—a case of typhoid fever.

It may be well here to quote an extract or two from a paper recently read before the Sanitary Congress at Birmingham, England, by Samuel Rideal, D. Sc., F. I. C., of London, England, (a gentleman to whom your Commission is indebted for other valuable information). He says:

"A question frequently raised is the possibility of an effluent conveying disease germs. By this time it is well known that fortunately pathogenic bacteria as a rule do not thrive much below blood heat, and that they are rapidly crowded out and destroyed by the ordinary bacteria existing in common waters, and still more by the immense

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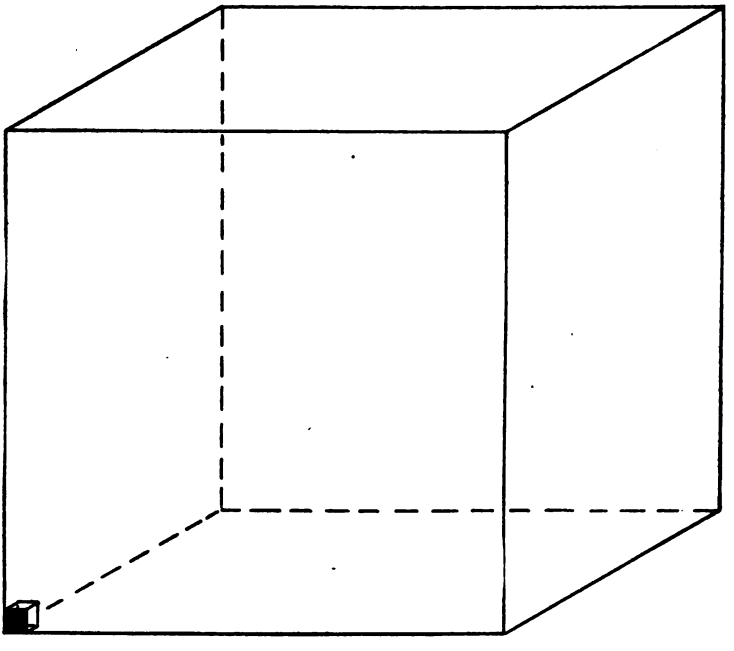
FIG. 3



THE LARGER CUBE REPRESENTS THE VOLUME OF SEWAGE FROM THE ENTIRE POPULATION OF THE CITY.

THE SMALLER CUBE REPRESENTS THAT DERIVED FROM THE FULL NUMBER OF TYPHOID PATIENTS WITH SAME PROPORTION OF TYPHOID CASES TO POPULATION AS EXISTED IN 1897.

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numbers present in sewage. I need hardly refer to the fact that the typhoid bacillus has only in rare cases been found even in waters and sewages to which it must obviously have penetrated. This disappearance is clearly explained by some experiments of Dr. Sims Woodhead at Exeter, when he found that crude sewages containing about half a million organisms per cubic centimetre when inoculated into the filtered effluent of a septic tank developed more than one thousand millions in five days, thus overwhelming any pathogenic bacteria that might be present. In the same Local Government Board inquiry Dr. Pickard specially investigated the typhoid microbe with reference to the action of crude sewage on it and to the effect of a filter bed on those germs which had survived a short exposure. He concluded that the sewage itself, even when sterilized, 'was not only a bad food, but an actual poison' to these bacteria; that in the septic tank they suffered a rapid destruction, and that the filter beds effect a further biological elimination, 'so that there is no chance whatever of the filtered effluent causing typhoid fever if passed into the river.'"

The Health Commissioner of Baltimore reported 362 cases of typhoid fever in Baltimore in 1897, very nearly one case for every day in the year.

The average duration of each case that recovers is estimated at 60 days, including the period of incubation, so that we may assume there were existing every day 60 cases of the disease in various stages.

Now, if we estimate that 100 gallons of water per day are used by each one of the sick, we have 6,000 gallons daily as liable to contain germs of this disease out of some 69⅓ millions of gallons, the estimated future flow of sewage from a population equal to that of 1897. That is about 95 hogsheads of sewage liable to contain germs of typhoid out of 1$\frac{1}{10}$ millions of such hogsheads daily discharged into the bay.

This proportion is shown graphically by diagram, figure 3.

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It is claimed, and we believe, that if proper attention be paid to the protection of our present water supply, and care be taken to inspect the sources whence milk is furnished to the city, there will be a marked reduction in the present typhoid rate. When, in addition, we have a properly constructed sewerage system, whereby cess-pools, no longer a necessity, will be in fact absolutely prohibited, we shall be rid of one of the readiest facilities for the conveyance of disease.

Excrementitious matter generally need never then be exposed to flies, which now pass freely from our present out-buildings or privies directly to the adjacent kitchens, where their contact with food means immediate pollution. That these insects are a potent means of disseminating disease does not admit of doubt.

In an address delivered before the Maryland Public Health Association in February, 1897, Dr. William Osler, F.R.S., of the Medical Faculty of Johns Hopkins University, remarked: "We may *confidently* expect, with the completion of a good sewerage system, the present (typhoid) death rate of Baltimore, about 40 per 100,000, to fall to that of the cities of the first class, from 4 to 8 per 100,000 inhabitants."

Surely with such conditions of improvement there need be little fear that an oyster reposing on its distant bed will suffer injury by contact with a wandering bacillus from one of the very small number of typhoid victims which may possibly still be found within our then carefully guarded city.

It would appear to be equally unreasonable to apprehend that the organisms of disease contained in the sewage can survive such dilution and dispersion and remain a menace of any importance to the oysters, there being at present no workable beds of merchantable oysters within several miles of the outlet heretofore recommended.

As it has been thought possible that oyster beds may in the future develop around the point of proposed outfall,

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it may be deemed the part of prudence to prohibit by law the taking of oysters for market within a distance of say four miles in all directions from such point. Should oysters hereafter be found there they need not be lost to commerce, but may be used under special license for transplanting to other localities, there being ample authority for the assertion that oysters exposed to and even inocculated with typhoid germs become freed from such germs in from one to three weeks after being transferred to a stream of clean sea water.*

With such provision there would be no more exposure of marketable oysters to disease germs than already exists and probably always will exist, for the oysters are now mainly taken from the more shallow waters along the shore and largely from the lateral estuaries, where they are surely more exposed to chances of defilement from the sewage of the cities and towns located on the banks of the several tributaries of the bay than will be the deep water oysters, or those of the bay generally, from the sewage of Baltimore.

An important consideration in favor of a discharge of the sewage into the bay not hitherto mentioned, is that with a gravity outfall the city provides itself with what may be regarded as a great safety outlet, less liable to be interfered with by accidents to machinery than is the case with other methods of disposal more dependent on pumping for removing the sewage as fast as collected.

However, if our fellow-citizens are not inclined to avail of this, the natural and most economical method of disposal, and should determine to have something else, leav-

* Proceedings of the Académie de Médicine of Paris, quoted in Appendix 4, Twenty-fourth Annual Report of the British Local Government Board for 1894–'95 on Oyster Culture in Relation to Disease, p. 174.

Report by Dr. Klein on his Bacteriological Researches in Appendix 2, Twenty-fourth Annual Report of the British Local Government Board for 1894–'95 on Oyster Culture in Relation to Disease, p. 120.

A paper by Professors W. A. Herdman, F. R. S., and Robert Boyce, read before the Royal Society January 19, 1899, and quoted in "Nature," vol, 59, p. 306.

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ing the economies of the dilution method to be enjoyed by our neighbors, whilst we make use of some much more expensive system, nothing remains for your Commission, under its instructions, than to point out such other method as seems to it available, though it be much more costly to construct and operate.

ALTERNATIVE PLANS.

In the report of this Commission made September 20, 1897, there were summarized three methods of disposal:

First. By dilution into the waters of the bay.

Second. By chemical precipitation of the solids and disposal of the effluent into the river or bay.

Third. By filtration upon lands in Anne Arundel County.

Of these the second was eliminated as offering no advantages when either the first or third could be made to serve efficiently the desired end, unless indeed as a temporary expedient, etc. The first and third methods were then discussed and their cost compared, with the resulting conclusion of the Commission to recommend the first.

In place of this, the Commission, under its instructions, might have been expected to recur to the third method, or filtration upon land, as the only alternative plan. However, since the publication of the report already referred to, there have been developed certain bacteriolytic processes of sewage treatment, which are now receiving much attention, particularly in England. For some of these great efficiency is claimed, and your Commission has deemed it proper to investigate these methods, to ascertain if by their aid the necessity for carrying the sewage to the agricultural filtratration fields can be avoided, and its purification effected in a degree sufficient to admit of its discharge into the Patapsco River at a point nearer to the city than hitherto deemed admissible, involving at the same time less outlay for construction and annual maintenance.

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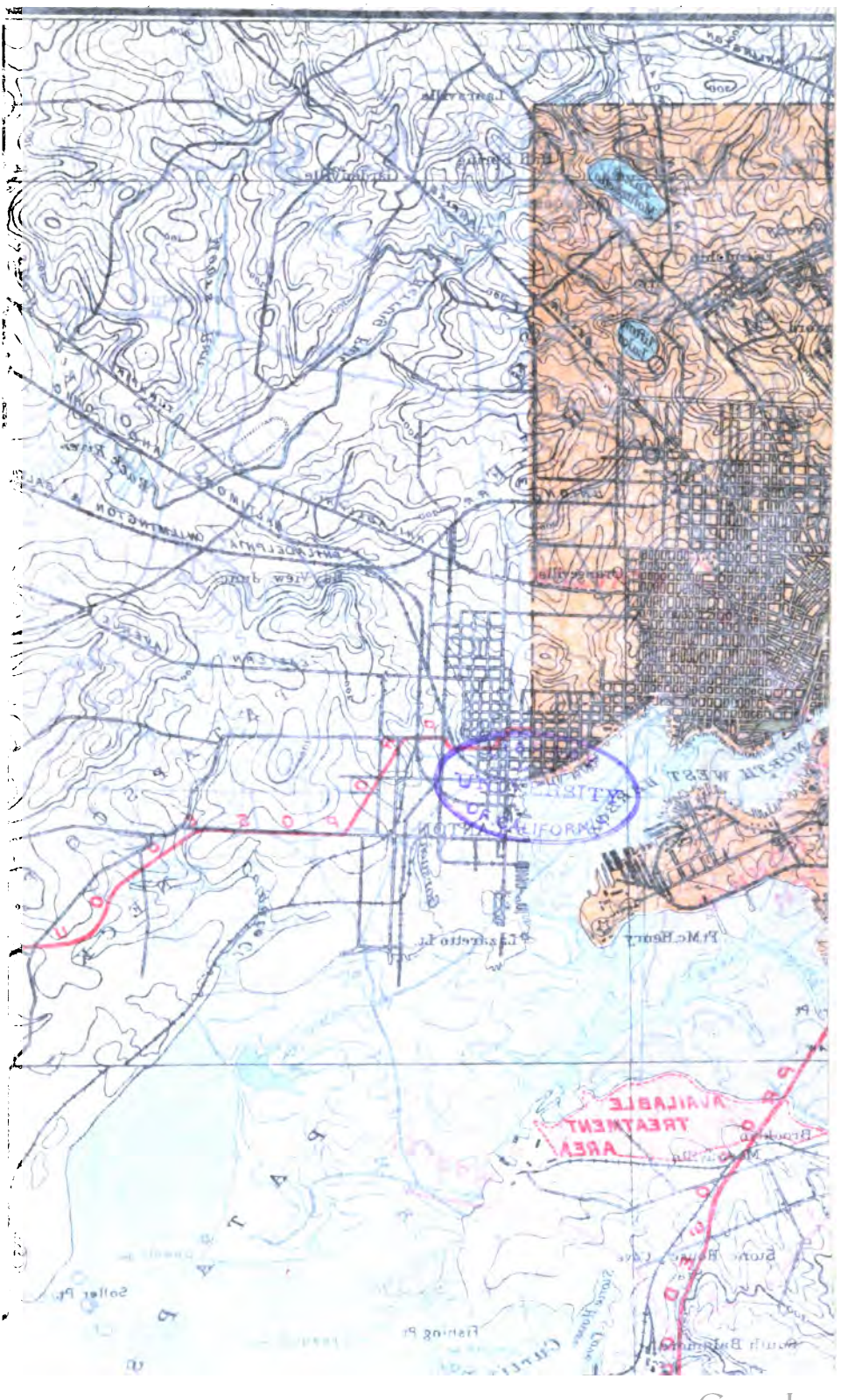

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It was suggested that the Commission should go abroad and examine for itself the working of these several modes of sewage treatment. This it was not possible to arrange immediately, owing to the home engagements of the several members, and it was concluded, with the approval of the Mayor, to engage instead the services of an English engineer to investigate and report upon the subject.

For this work the services of Mr. James Mansergh, of London, Vice-President of the Institution of Civil Engineers, Member of the Institution of Mechanical Engineers, etc., etc., a civil engineer of great experience and much distinction, were obtained. His report is presented herewith. (See Appendix F). Its conclusions are considered further on.

Of the two methods discussed in detail in the former report of the Commission, the first proposed to collect and convey the sewage to the eastward on its way to the bay; the other was designed, by a system flowing in an opposite direction, to collect and convey it to the southward, and under the Patapsco River to the Anne Arundel shore on its way to the filtration fields. (See Plate II.)

Both these plans have been revised with some modification of the original dimensions, and in the case of Project C, with a change of location of a portion of the lines of outfall, involving thereby some change in the location of the fields on which the outfall would be received. The details of these revisions are fully given in Appendixes B and D, where the revision of Project C is termed Project D, and that of Project K becomes Project L.

It has also been deemed expedient to include in the capital cost of the works the various district sewers, leaving only the smaller street and alley laterals, as the "reticulation system," to be provided for by direct assessment on the property immediately benefited. In the report of September 20, 1897, the cost of these district mains was included in the reticulation system, but in all the estimates

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of the present report their cost forms part of the amount to be raised by a general loan.

This revised plan, hereinafter referred to as Project D, can be made available in its first installation for a population in connection with the sewers of about 200,000 from the low-level districts at an estimated cost in capital outlay of.....	$3,188,118
It will take from three to five years from the starting of the work to effect its progress to this extent. During this time there will be also constructed the system of laterals, which we have termed the reticulation system, to the extent needed to connect with the sewers the 200,000 population estimated for. The cost of these laterals should be met by a direct assessment against the property at once benefited thereby, as for street improvements. It is estimated at $1,500,000. This first opening of a portion of the low-level system may be followed by a commencement of work on the high-level system, and the extension to completion of the low-level system with such degree of rapidity only as the financial condition of the city and the demands of an increasing population may make necessary or desirable. These extensions, when sufficiently developed in future years to serve a population of one million, are estimated to involve a further capital outlay of.....	6,672,123
And of a further sum for the laterals of the reticulation system, to be assessed as before, against the property directly benefited, gradually, and as the various districts are brought into connection with the system, at a cost of $3,080,000.00, making a total outlay when the works are completed, to be met by city loans, amounting to.....	$9,860,241
And of assessments directly against the property benefited....	4,580,000
A grand total cost.....	$14,440,241

It is quite impossible at this stage of the problem to determine the property frontage against which the cost of the reticulation will be assessed, for there is a large area of the city in which the streets are not as yet laid out or established. However, from the best data available, it is believed that an assessment of $1.25 per front foot will fully cover the cost of this portion of the work.

The total cost of Filtration Project C was given in the report of 1897 as.....	$17,476,803
And now, as revised for Project D.....	14,440,241
A reduction of.....	$3,036,562

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A revision of Project K, hereinafter in its revised form termed Project L, is here submitted:

The cost of Project L, at first installation serving a population in connection with the sewers of about 200,000, and including cost of district sewers, is estimated at a capital sum, to be provided by loan, of	* $3,202,846
The construction of the laterals or reticulation system, by which connection will be effected with the 200,000 population to be first served, will go on simultaneously with the outfall system at an estimated cost to be assessed against the property directly benefited of $1,500,000.	
The extension of the works to take in the other districts of the city will proceed at such rate as may be deemed expedient, and, when developed to an extent to serve the forecast population of one million, is estimated to cost the additional capital sum of	2,370,485
And a further sum for the laterals of the reticulation system, to be assessed against the property directly benefited, of $3,080,000.00, making the total estimated outlay, when the works are completed, to be met by city loans	$5,573,331
And by assessments against property benefited	4,580,000
A grand total cost for the revised Dilution Project L of	$10,153,331
The total cost of Dilution Project K was given in the report of 1897 as	$10,495,167
And now as revised for Project L	* 10,153,331
A reduction of	$341,836

As the cost of the reticulation is assumed to be the same with either project, and as it is proposed to meet it by direct assessment on the properties benefited, further discussion of the question of the cost of the different projects will have reference only to the amounts to be raised for their construction by loan on the credit of the city.

*It is possible that the estimate made herein for submerged outfall mains may be reduced by about $144,000 for the first installation and $638,000 for the completed work, if anticipated results in improved methods of constructing and laying such mains, now proposed elsewhere, should be realized.

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COMPARISON OF COST.

	For first installation, say within 5 years from first undertaking of the work	For completed work, say in 25 or 30 years when the population has reached a million.
The revised Filtration Project D requires.....	$3,188,118 00	$9,860,241 00
The revised Dilution Project L requires at the same stages of progress.....	3,202,846 00	5,573,331 00
	$14,728 00	$4,286,910 00

A difference of $14,728 in favor of Project D at first installation, and a difference of $4,286,910 in favor of Project L at completion of work.

The annual cost of maintenance and operation of these projects is estimated to be—

	On First Installation.	On Completed Work.
For Project D.....	$244,171 00	$781,683 00
For Project L.....	198,179 00	361,461 00
Difference in annual cost in favor of Project L.	$45,992 00	$420,222 00

SPECIAL SYSTEMS OF SEWAGE PURIFICATION.

Having presented in their revised form estimates for the disposal of the sewage under Projects D and L, your Commission will now discuss briefly the availibility of some special methods of sewage purification which have been brought to its attention.

The investigation of such systems as are now commanding attention abroad was entrusted, as already stated, to Mr. James Mansergh, C.E., of London, from whom we have a comprehensive report on the subject, accompanied by illustrative drawings and with a detailed discussion by Dr. G. Sims Woodhead, F.R.S.E., of the bacteriolytic action induced in the filters employed for effecting this purification. This places your Commission in position to decide upon the advisability of introducing at this time any of these methods for the purpose of avoiding the great cost of disposing of the sewage of Baltimore upon farming lands in Anne Arundel County.

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It seems only necessary here for your Commission to announce the conclusions at which it arrives after full consideration of the information derived therefrom, as well as from the result of its own investigations in regard to the several systems.

The various methods of treatment which have received consideration are:

1st. The Waring system of bacterial oxidation.

2d. The Pennsylvania Sanitation Company's method of filtration.

3d. The Scott Moncrieff system of anaerobic treatment, followed by filtration through a series of thin beds superposed as trays one above another, the sewage being aerated as it drops through the intervals between the trays.

4th. The Dibdin system of bacterial filtration.

5th. The Cameron system of septic tank treatment, followed by filtration in aerobic beds similar to Dibdin's.

6th. The Lowcock system of filtration and forced aeration, involving the same principles as used by Waring.

7th. The Ferozone-Polarite process.

8th. Ducat's self-acting bacterial filters.

Whilst some of these processes have proved themselves effective and promising, and whilst all are claimed by their proprietors to fully meet the requirements demanded of your Commission, it must be recognized that the scale on which they have been tested is in every instance far below that which would be required for the treatment of the sewage of Baltimore, even at first installation.

Mr. Mansergh remarks (See Part III. of his report—Appendix F):

"Judging the Baltimore sewage problem from the bacterial standpoint at this distance there are two prominent features which immediately attract attention. The first is the enormous volume of sewage per head per day which your Commission is compelled to provide for, owing to what I cannot help thinking to be an extravagant user of water, prevailing I know all over the States.

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"This is four times what we have to deal with here, and it means, of course, that the works for similar cases would be four times larger with you than with us. * * * *

"This means that the cost of installing large structural works for these new and not fully developed processes is greatly increased in your case, and if failure should result the consequences would be serious.

"There is also the consideration that diluted sewage like that of Baltimore may develop characteristics during bacterial treatment which have not appeared here. Presumably the task of cleansing the weak sewage ought to be easier than strong sewage, but this is by no means determined.

"The second feature at Baltimore is one wholly in favor of the bacterial processes, and it is the fact that you have the sea or large flowing rivers into which the filtrate would be discharged. Such waters are fully oxygenated and are therefore specially adapted for the reception of bacterial filtrates.

"With a sea outlet or an outfall into a big river near to the sea, I think the experience here would justify you in installing the Dibdin or the septic tank process for a small population of 10,000 or 20,000 persons, if an auxiliary means of dealing with the excess rain is provided.

"It is a long step from the 120,000 (imperial) gallons dealt with by the Dibdin system at Sutton, or from the 31,000 (imp.) gallons dealt with by the septic tank at Exeter, to the 40,000,000 (imp.) gallons at Baltimore, increasing in the future to a possible 120,000,000 (imp.) gallons, and one could wish there were a few intermediate examples.

"The big problem is, of course, merely the multiplication of the smaller ones, and there ought to be no insuperable difficulty in applying what has been achieved to the larger case, but it would be prudent to proceed tentatively."

The views entertained by your Commission, being in accord with those of Mr. Mansergh, it finds no warrant in

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present experience for recommending the adoption, on the scale which the full requirements of Baltimore would involve, of any one of the treatment processes thus far considered.

At the same time it fully recognizes that one or more of them may prove available for the treatment of the sewage of some of our outlying districts, and may, if future experience sustains the claims and anticipations of their advocates, yet become adequate to our service on a larger scale.

It may be said further that the success so far attained with some of these bacterial processes seems to have established their superiority to any form of chemical precipitation, a method which, in our former report, your Commission concluded had no advantages for application to the sewage of Baltimore.

The fact that by bacteriolytic action the suspended matter in the sewage is dissolved and eliminated, instead of being precipitated by aid of expensive chemicals into a *sludge* of no economic value and removable only at additional cost, is an element which alone is likely to control the determination of the method of treatment wherever disposal by filtration is deemed essential.

We now revert to a further consideration of Project D—the agricultural filtration scheme.

AGRICULTURAL FILTRATION ON ANNE ARUNDEL LANDS.

We have estimated that the first installation of this project will cost $3,188,118, and will occupy in construction a period of perhaps five years from its commencement. It will include practically the whole of the low-level service, and if efficiently carried out should intercept nearly all sewage now reaching the inner harbor, and should rid the city of the intolerable basin nuisance, besides effecting the sub-soil drainage of the business portion of the

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city, and making possible dry basements and sub-cellars, where these cannot now be had.

This sewage, from some 200,000 persons, will be pumped to lands at Glen Burnie through one main of 56 inches in diameter.

Although this first installation of the low-level system has been limited in extent to a connection of 200,000 persons, the sewers and district mains will serve with extended interceptors and additional reticulation for a population which has been forecast as 600,000 eventually.

The high-level system might be under construction at the same time, but it is assumed that for financial reasons the city authorities may prefer to limit the rate of progress to the low-level only, as estimated.

If such be the actual method of construction adopted, it will be possible at this stage of the work to modify the plans, if found expedient so to do.

AGRICULTURAL FILTRATION COMBINED WITH SPECIAL TREATMENT.

Should the interval occupied in the construction of this first stage of the work have served to demonstrate the capacity of the bacteriolytic method of sewage treatment to cope with the remaining or high-level portion of the Baltimore sewage, advantage may be taken of the fact to establish a treatment plant in the neighborhood of the village of Masonville, on the south shore of the Patapsco, with a considerable saving over the capital outlay necessary for the extension of the whole system to the agricultural filtration fields.

If this modification should prove to be justifiable the Western High-Level Interceptor will be constructed substantially as in Project D. The sewage from this source will enter the closed main at about Eutaw and Franklin streets, or say at an elevation of 90 feet above tide, and will be turned into the outfall main, used at the outstart

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by the low-level system, and will flow through that main to Glen Burnie by gravity. (See Appendix C and Plate II.)

The low-level sewage, theretofore pumped to Glen Burnie against a head of 112 feet, will then be pumped only to Masonville against a head of 40 feet.

At Masonville such works and filter beds as the method adopted may require will be constructed and gradually extended as the increasing number of house connections may make necessary.

The construction of the Eastern High-Level Interceptor may be deferred until the treatment works are in operation.

If the result of their working be satisfactory this interceptor, instead of being so located as to deliver its sewage by gravity on the Anne Arundel fields, as by Project D, will be lowered 60 feet to a contour adequate only for delivery of the sewage to Masonville. (See Plates III. and V.)

This arrangement will intercept and cut off from the low-level system perhaps as much as one-sixth of its sewage, leaving at a minimum the volume to be pumped to Masonville. It will, perhaps, require some modification in the pumping plant, but no increase of steam power.

It will avoid the necessity for the acquisition and use of some 3,000 additional acres of farming land, and also for the laying down of four 56-inch mains, aggregating in length 26½ miles, between Masonville and the more distant fields, and will save the cost of the increased pumping plant required to force the sewage to such distance.

It is estimated that with this modification the works may be completed for a sum of $3;411,870, in addition to the cost of first installation, making the entire capital cost of works under what we will term Project D-E, $6,599,988. For details of this estimate see Appendix C.

If, on effecting the first installation of Project D, there be not found sufficient warrant to justify the adoption of

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the bacteriolytic treatment plant at Masonville, it will only remain to construct the high-level system and extend that of the low-level on the general lines of Project D, as described in Appendix B, at an aggregate additional cost, as already stated, of $6,672,123.

RECOMMENDATIONS.

The Sewerage Commission, under its instructions as set forth on the first page of this report, but without a change in its belief that the plan first recommended is in every way the *best method* of disposal of the sewage of Baltimore, finds the *best alternative plan* to be as follows:

The construction of the *low-level system* of Project D, as described in detail in Appendix B, to the extent at first, however, only of a service connection to reach a population of about 200,000, and with delivery of the sewage on farming lands in the neighborhood of Glen Burnie, in Anne Arundel County, at an estimated capital cost of $3,188,118.

These sewers will have capacity for a population of about 600,000, although starting with but about one-third of that number in connection, and will be made to subserve a great part of the city lying south of North avenue and east of Eutaw street, together with a considerable section west of Eutaw street and south of Franklin street, and also a great part of the Federal Hill and Locust Point districts.

Further construction need not be undertaken until the low-level system is in successful operation.

It can then be determined, with the light which will by that time have been developed through experience in the bacteriolytic methods of sewage treatment, at home and abroad, whether the extension shall be on the general plan of Project D, involving an additional outlay of $6,672,123, or by the modification outlined as Project D-E, at a further cost of only $3,411,870.

As the first installation here recommended at a cost of

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3¼ millions of dollars will be, by either plan, complete in itself, as far as it goes, and will cure the basin nuisance, the City can, on completion of this stage, rest long enough to review its action before issuing a further loan for its extension.

In the meantime population will have increased, upwards of six millions of the existing burthen of debt will have matured, and it may be expected will have been paid off, thus leaving the city in better shape to place new loans on the market.

For these reasons it appears best to your Commission to discuss the financial aspect of the question with reference only to this first stage of the proposed work.

Before proceeding to this discussion, however, the Commission desires to state that, should the method of disposal definitively adopted by the Mayor and City Council be that to which the Commission has given preference, to wit, crude discharge into the Chesapeake Bay, and should it ever be found that such discharge has become objectionable, it will not be more difficult or more costly to prepare filter beds on the bay shore, for the purification of the sewage, than to establish such a plant at Masonville.

This has been estimated for as Project L-M. (Appendix E.)

COMPARATIVE CAPITAL COST OF THE SEVERAL PROJECTS.

Project.	L.	L–M.	D.	D–E.
Character of Disposal.	Crude discharge into the Bay.	Discharge into the Bay after special treatment.	Agricultural filtration for the whole of the sewage.	Agricultural filtration for the low-level sewage only, and special treatment of the remainder at Masonville.
Cost at first installation.	$3,202,846	$3,202,846	$3,188,118	$3,188,118
Cost at completion for the needs of one million population.....	5,573,331	5,860,331	9,860,241	6,479,547

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ANNUAL COST OF MAINTENANCE AND OPERATION OF THE SEVERAL PROJECTS.

PROJECT.	L.	L-M.	D.	D-E.
At first installation.....	$198,179	No data for estimate available.	$244,171	No data for estimate available.
At final completion.....	361,461		781,683	

WAYS AND MEANS.

The estimates of the Commission show that the cost of the first installation, to serve the lower portions of the city and intercept the filth now reaching the basin, will be about three and a quarter millions of dollars, and is, at that stage, substantially the same for every project considered.

If this amount be raised by a 3½ per cent. loan, to run for fifty years, it is thought that a premium of at least 10 per cent. can be realized on its sale, yielding, say $325,000. It is assumed that this premium, when covered into the sinking fund, may be so invested as to yield 3 per cent. per annum.

The reinvestment of the accruing interest at this rate will, with the invested premium, amount in fifty years, at the maturity of the loan, to say $1,425,000.

The remaining amount, $1,825,000, required to pay off the loan at maturity, must be met by an annual payment to the sinking fund of a sum which, invested with its accruing interest at say 3 per cent., shall yield the required amount when the loan falls due.

The sum of $16,800 so invested annually will suffice for this, so that the annual payments on account of this loan will be—

For interest on loan of $3,250,000 at 3½%.....	$113,750
And for payment to sinking fund.....	16,800
A total of.....	$130,550

This amount is included in the estimates of annual cost of maintenance as here shown for the respective projects at first installation.

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	L. Crude Discharge into the Bay.	D. Agricultural Filtration at Glen Burnie.
Total annual cost.....	$198,179.00	$244,170.00
Deduct allowance for depreciation and renewals.....	33,407.00	52,015.00
Leaves annual cost for interest, sinking fund and operation..	$164,772.00	$192,155.00
Requiring a tax rate per $100 of assessed valuation, respectively of.....	5½ cents.	6½ cents.

Whilst for proper comparison of the relative yearly cost of the different projects it is necessary to include an allowance for depreciation and renewals, as shown above, it does not seem either reasonable or proper to tax the people at the outstart to the extent necessary to raise and maintain a fund for such purpose. There should be no renewals for many years, and it will be time enough to establish such a fund when the works are approaching completion and there can be adopted a regular system of sewer rates, duly proportioned to the amount of sewage emanating from the various classes of houses, tenements and manufacturing establishments.

Hence, in our estimate of actual yearly cost, we omit this allowance for depreciation and provide only for interest on the loan, provision for the sinking fund and operation of the works.

In advance of the establishment of sewer rates the actual yearly cost must be met by general taxation, and for this purpose we find, on the assessment basis for next year, which may be taken at 300 millions of dollars, that a levy of 5½ cents for Project L and 6½ cents for Project D on every hundred dollars of assessed valuation will yield an amount sufficient to cover the annual cost of the first installation.

That the sewer rates which will eventually supersede the general tax need not be burthensome is readily seen.

In our report of September, 1897, it was shown that on an average of the previous three years 92,568 loads of filth were removed each year from cess-pools within the city

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at a cost to the citizens of $2.50 per load. We were unable to ascertain the number of pits from which this volume was removed, and took the total number of houses in the city, then estimated at 92,779, as each contributing about one load to the total, at a cost of $2.50 per house.

As the necessity for maintaining cess-pools will cease as soon as connection is made with the sewerage system, there will then be at once an end to the constantly recurring expense of emptying these foul receptacles; a cost which now bears very unequally upon property-holders, and most severely upon the owners of small tenements with pits of limited capacity. These rarely escape an annual emptying at a cost of from $2.50 to $7.50; whilst no necessity for such cleansing attaches to property favored by connection with existing drains, which is thus saved both nuisance and expense.

If the 200,000 population, which will be brought into connnection with the system as first installed, occupy a proportionate number of houses to those accommodating the whole population of the city, we shall have about 35,684 house connections, from which an average rental of say $4.60 will meet the annual charges of Project L, and a rental of say $5.40 those of Project D.

If from these rates we deduct but $2.50 as the cost of present annual cleansing, we find that the enjoyment of a thorough and cleanly system of sewerage may be had at an annual cost to each house, which need not be more than from $2.10 to $2.90 in excess of what is now paid each year under present filthy and unhealthy conditions.

PROPOSED SEWERAGE COMPANY.

It has been suggested that the City of Baltimore cannot afford to incur the further burthen of debt which construction of a sewerage system will involve, and that consequently private capital should be enlisted through the medium of a stock company, which can be organized for the purpose of taking over the work of constructing and operating such a system.

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Although this is not a question which this Commission might have been expected to discuss, it yet seems proper to give it consideration, and to present some views of the practical objections thereto.

Such a franchise, if granted, must of course include the right to locate the sewers as the engineers of the company may find expedient. There will be no end of conflict as to interferences between the proposed sewers and the existing storm-water drains, water mains and electric conduits. These differences may not be easily nor cheaply reconciled, particularly when it is found to be to the interest of the private corporation to spare its own treasury at the expense of that of the City.

As there would no doubt be included in the franchise of the private corporation provision for the city in the future to take over the entire plant, it would be the City's interest to have the work done in the most thorough manner. The interest of the company would, however, be to have the cost of construction kept as low as possible, consistently with a certain degree of stability and endurance, which would be measured by the proposed or conjectured length of its tenure of the franchise.

This difference of interest between the City and the contracting company will be apt to result in imperfect work, leaking sewers, involving unsanitary conditions, more or less obscure, but not the less dangerous because unobserved and unknown.

The contracting company will look for its profits to come from the densely built portions of the city, and will naturally resist the demand for extensions until it be deemed that a paying population can be reached. This has been the experience at Galveston, where we learn the city is now trying to get rid of the contracting company.

Of course, private capital will look for and require a larger profit than the three per cent. rate, or less, at which the city is now able to borrow. This profit must be high enough to cover the cost of blunders, accidents, damages

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and all possible contingencies, though these unfavorable conditions may never occur.

It would surely seem that, as the householders will in any event be charged a rate high enough to cover these contingencies, their advantage would be found in doing the work themselves, and paying no higher annual rate than sufficient to cover the cost of administration of the works.

It has been suggested that a private corporation will readily undertake to pay a handsome annual bonus to the City for the franchise. This is no doubt the case, but what does it mean? Simply that the contracting company must have the right to charge the householder a rate sufficiently high not only to cover all the proper expenses and contingencies to which we have referred, together with the dividends to the company's stockholders, but high enough to cover also the amount of bonus to be paid the City.

This scheme becomes, therefore, as a measure of economy to the citizens, a mere delusion and a snare. If they have, in addition to the annual cost of operating the works, to pay the profits or dividends of the contracting corporation and its bonus to the City, they might as well themselves pay the cost of operating the works, tax themselves for the bonus, save altogether the sum that is to go out in dividends to the stockholders and have into the bargain the entire control of their works.

The experience of New Orleans in the attempt which that city has made to save itself the capital outlay for a sewerage system should not be overlooked.

As far back as 1880 a franchise was granted to the New Orleans Sewerage Company to sewer the city. The company was organized with a prominent and trusted citizen at its head. Able engineers were consulted and plans prepared.

The result up to the present time is simply nothing accomplished. A few hundred feet of sewer only have been con-

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structed. No part of the work is in operation. The contracting company, apparently conducted for the benefit of individuals, stockholders and contractors, and not for that of the city, is reported to have failed, and the city is now legislating to take the whole scheme into its own hands and raise the amount of money necessary to enable it to undertake and press forward the construction of the works by its own officers.

CONCENTRATION OF ALL SEWER AND DRAIN CONSTRUCTION.

Your Commission, during its investigations, has been repeatedly asked if it be advisable to continue the construction of storm-water drains, or sewers as they are popularly termed, which are from time to time ordered to be built by ordinance of the Mayor and City Council.

It has always replied that, whilst it is advisable and often necessary to expend money to repair and maintain existing drains, no others should be constructed until the general system of sewerage is adopted. Thereafter all drains and sewers should be designed by the same department, and should be constructed with reference to general requirements and under the responsibilty of determining when the necessity for the undertaking really exists. It will then be time enough to ask for authority to construct.

In the absence of a comprehensive general design, far too much money has been already expended in these constructions, some of which will have to be altered or rebuilt in the future.

SELECTION OF PLAN.

There should be no further delay in deciding what is the system of sewerage construction to be adopted by the City.

This Commission has reduced the proposition, as it believes, to its simplest terms, and the Mayor and City Council must determine which of the two methods of disposal shall be adopted.

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I. Crude discharge into Chesapeake Bay (Project L), with possible future modification (Project L-M).

II. Filtration on land in Anne Arundel County (Project D), with possible future modification (Project D-E).

The question must be decided by weighing the greater capital outlay and greater annual cost of the more complicated Project D, against the possibility, real or sentimental, of injury to the oyster interests in carrying to completion the more simple arrangements of Project L.

That there is pressing need for prompt decision in this matter must be recognized when we state that the main intercepting and district sewers, many of which will be of large size, should be located, and if possible constructed, in advance of other works.

The sewage flows through these conduits by gravity, and in order to maintain velocity adequate to carry all matter held in suspension and avoid offensive deposits, adjustments somewhat intricate have been involved in the designs so as to effect the crossings of the railway tunnels, the passage of Jones' Falls and the interference of large storm-water drains. It has even been necessary to modify the form of some of the latter in order to adjust the interferences.

With the peculiar topographical features of Baltimore, it may be well nigh impossible to further change the location of the great sewers to avoid interference with water mains, gas pipes, electrical subways and surface railroads, and hence the sooner the city locates its sewers and defines its requirements in its own streets the better. What may have to be done in the case of certain streets through which these main sewers must pass, and which are already partly, if not wholly occupied, is not for this Commission to consider. Its duty is fully performed in urging upon the attention of the Mayor and City Council the expediency of avoiding further delay.

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The difficulties here referred to apply only to the great intercepting and district sewers. No trouble is anticipated in so locating the small lateral sewers of the reticulation system, partly through the alleys and under the sidewalks, as to avoid interference with other works.

If the action here recommended be taken and a decision be made by the Mayor and City Council as to the plan and method of disposal to be adopted, this should be immediately followed by fixing the location of the great and more important sewers. Steps should also be taken to have carefully prepared, in advance of the meeting of the General Assembly in January, 1900, such form of enabling act as may be desirable, and under which, if enacted, the City may take measures to acquire the land needed for the works and the funds necessary for their execution.

If, as is now to be feared, there may be much further delay before there be opportunity to submit for *referendum* any enabling act so passed, engineers may be advantageously employed, under temporary appropriations by the Mayor and City Council, in revising and perfecting the location of the work and in preparing for its letting under the system which the authorities, in their wisdom, may deem most advantageous to the interests of the city.

It cannot be too strongly impressed upon the city authorities that in work of this magnitude every dollar spent under a competent engineer in preparation and revision is returned many fold in the economies thereby effected.

CONCLUSION.

The obligation of the Commission to those who, during its earlier investigations, aided it in various ways was expressed in terms of appreciation in the last report.

It now desires to make its acknowledgments for valuable information and advice, more recently received, to Professors Ira Remsen and Wm. H. Welch, of Johns Hopkins University; to Prof. G. Sims Woodhead, of the University

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Messrs.	Jos. Garfield, C. E.,	Wolverhampton, England.
	Thos. Hewson, C. E.,	Leeds, "
	George Reid, M. D.,	Stafford, "

Your Commission desires, at the close of its labor, to place on record its appreciation of the efficient service rendered by Mr. Kenneth Allen, its Principal Assistant Engineer, who has had charge of all the details of its investigations, revision and estimates.

Mr. Charles E. Taylor, as Assistant Engineer, has conducted the field work made necessary by the revision of the line, and has skillfully executed the required map work.

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As heretofore, Mr. C. L. Rector has had charge of the accounts and correspondence of the Commission and has performed his several duties with intelligence and satisfaction.

In conclusion, the Commission expresses the hope that the result of its labors may be found acceptable, and that from the recommendations of this report a suitable plan may be adopted, under which the sewerage of the City may be undertaken without further delay.

The entire work submitted to the Commission being concluded, and its duty completed by the submission of this report, it respectfully asks that its report be accepted and that the Commission be discharged.

All of which is respectfully submitted.

MENDES COHEN,
F. H. HAMBLETON,
E. L. BARTLETT,
} *Sewerage Commission of the City of Baltimore.*

BALTIMORE, 22nd May, 1899.

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APPENDIX.

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APPENDIX A.

ELEMENTS INVOLVED IN REVISION OF COST.

In the revision of estimated cost a reduction has been made by reducing the dimensions of all sewers from those described and estimated for by the Consulting Engineers, as given in the report of the Commission dated September 20, 1897.

The warrant for this change is to be found in the following statement of facts:

When the data on which to base their estimates were furnished to the Consulting Engineers, the Water Department claimed to be supplying daily an amount of water reaching at a maximum 72,000,000 gallons, with a daily average consumption of 120 gallons per head of population.*

Whilst this amount was recognized as excessively large the Consulting Engineers did not feel warranted in basing their calculation on any less quantity.

Taking this, therefore, as the actual consumption, they added an amount to cover infiltration of ground-water, some accession of storm-water, and an uncertain quantity required for flushing, and arrived at a total of 150 gallons per head of population as the amount of sewage for which it would be necessary to provide, and on this quantity their estimates of cost were based.

After the report of the Consulting Engineers was made up, a change of administration of the Water Department led to a revision of data, when it was ascertained that the maximum daily consumption of water did not quite reach 52,000,000 gallons, or about 95 gallons per head of population.

The annual report of the Water Department for the year 1897 gives the average daily consumption throughout the year as 88 gallons per head of population served. Your Commission has based its revised estimate on this average daily consumption, 88 gallons per head, and has

*Report to the President and Members of the Baltimore Water Board by Samuel M. Gray, Consulting Engineer, October, 1896, pp. 3 and 9.

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added thereto an amount even larger in proportion than allowed by the Consulting Engineers to cover flushing, influx of ground-water and contingencies, thus arriving at 117 gallons as the average amount of sewage to be provided for daily per head of population.

As, however, the pumping plant and discharge mains must be adequate to provide for the maximum flow which may at any time reach them, separate estimates have been made of the probable maximum flow in different portions of the city.

For the low-level districts 140 gallons per head of population is deemed amply sufficient to cover all inflow of ground-water, flushing, etc., whilst for the high-level districts 106 gallons per head is found to be an equally full allowance.

On these estimates of volume the dimensions of the various intercepting sewers have been re-calculated and the revised estimates are based thereon.

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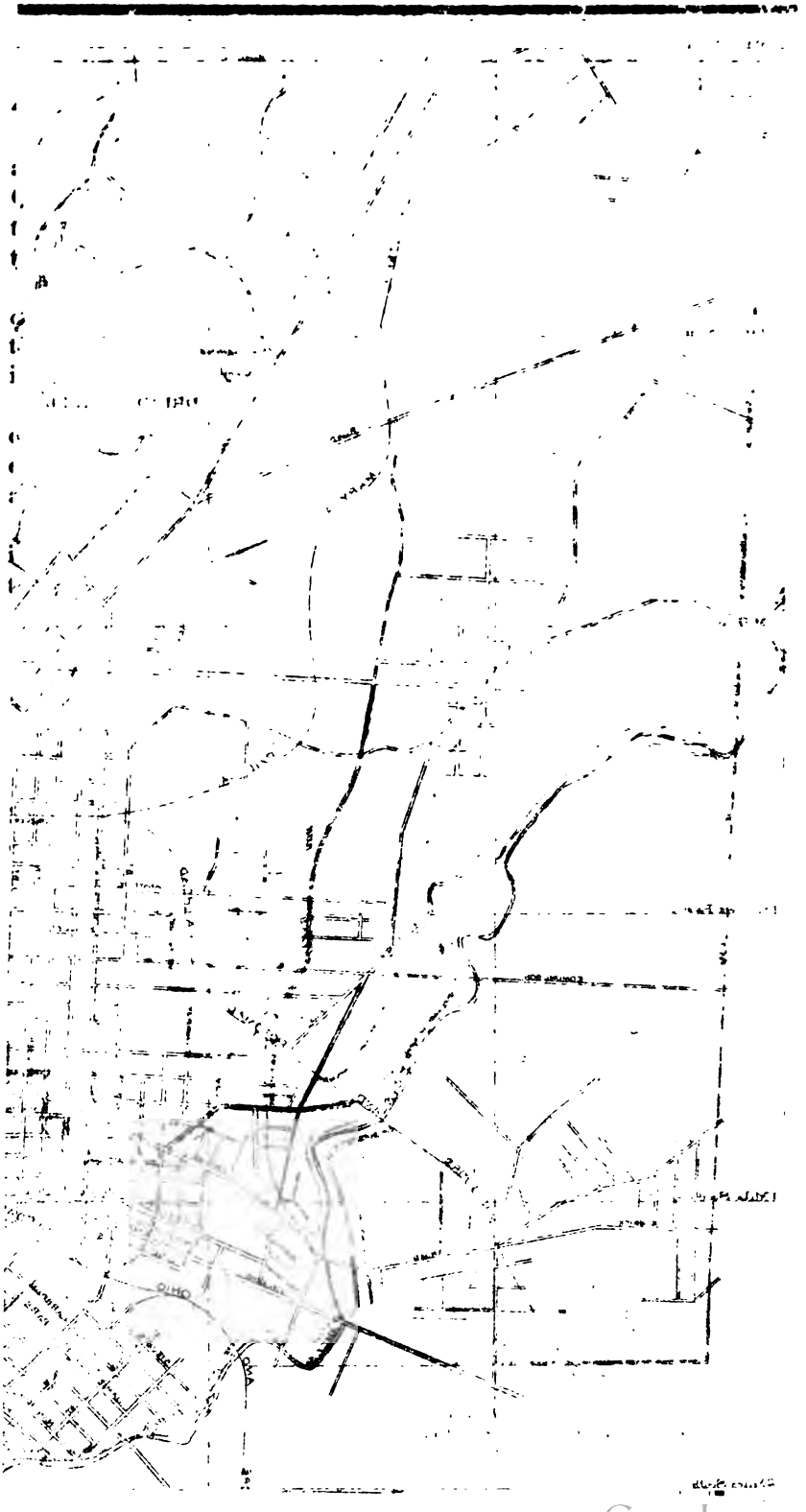

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APPENDIX B.

PROJECT D.

The location and profiles of the intercepting sewers of Project D are shown by Plates III. and IV. and are as described below. These are approximate only, and may, with their diameters, require slight modification when the time for construction arrives.

First Installation for Low-Level Service.

Whilst the population to be provided for at first installation is but 200,000, the dimensions of the sewers are adequate for the population of 600,000, which may ultimately be connected therewith.

The Western Low-Level Interceptor.

This runs from the intersection of Putnam and Russell streets along the latter to Bush street, with a diameter of 3 feet 3 inches. It continues thence with a diameter of 4 feet 6 inches to Stockholm street, when it is enlarged to a diameter of 5 feet 6 inches, and runs on Stockholm street to the pumping station. For first installation, the construction on Russell street west of Ostend street, may be deferred and is not included in the estimate.

The Eastern Low-Level Interceptor.

This is designed to take about four million gallons per day from territory now beyond the eastern city limits, and runs on Boston street from the city limits to the Harris Creek Drain with a diameter of 2 feet 9 inches. Passing under this drain by a siphon of two 18-inch cast-iron pipes, it continues with a diameter of 4 feet 3 inches on Boston and Aliceanna streets to Washington street, where it is increased in size to 5 feet 9 inches, and runs on Aliceanna street, Caroline street, Eastern avenue and Albemarle street to Pratt street. From this point it has a diameter of 6 feet 3 inches, and continues in Albemarle street to Lom-

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bard street, to Front street and to a point opposite Water street. Thence the size is increased to 7 feet 6 inches as far as the west side of Centre Market Space, Jones' Falls being crossed by an inverted siphon composed of two 36-inch steel pipes, laid in a brick-lined tunnel. From Centre Market Space the line continues on Water, Calvert, Lombard, Light and Balderston streets to Charles street with a diameter of 7 feet 9 inches, and thence on Charles street to York street with a diameter of 8 feet. Here the sewage from the York Street Interceptor is received and the diameter is increased to 8 feet 3 inches, and the line continues on Charles, Montgomery and Leadenhall streets to the pumping station at Stockholm street. For first installation the portion of this interceptor east of the Harris Creek Drain has not been included in the estimate.

The Locust Point Interceptor.

This starts from Garrett avenue and runs on Clement street to. Hull street with a diameter of 18 inches; thence on Clement street to Allen street with a diameter of 21 inches; thence on Allen street to Claggett street with a diameter of 2 feet 3 inches; thence to and along Winder street to Marshall street with a diameter of 2 feet 9 inches; thence on Winder, Race, Barney and Leadenhall streets to Fort avenue with a diameter of 3 feet 3 inches, and from Fort avenue to the pumping station at Stockholm street with a diameter of 4 feet 3 inches. The construction of the portion of this interceptor beyond the intersection of Barney and Race streets may be deferred until after first installation, and is not included in the estimate.

The York Street Interceptor.

This begins at a point in Clement street about 200 feet east of the centre of Jackson street, runs northerly and then westerly through private property to Jackson street, to West street, to Belt street, through the latter and private property to Rupert street, to Montgomery street, to Covington street, to Hughes avenue and to Battery avenue, with a diameter of 15 inches. From Hughes avenue it continues with a diameter of 20 inches through Battery avenue and York street to Charles street, where it unites with the Eastern Low-Level Interceptor. The construction of the portion of this interceptor beyond the intersection of Hughes and Battery avenues may be deferred until after first installation, and is not included in the estimate.

The velocities attained in the low-level interceptors, when running half full, are as follows:

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Western Low-Level Interceptor, four feet per second; Eastern Low-Level Interceptor, four feet per second east of Washington street and west of Front street. Between those two points the gradient is reduced so as to provide a velocity of three and one-half feet per second, in order to be sufficiently low at Washington street to avoid an inverted siphon. The Locust Point and York Street Interceptors are designed for a velocity of but three feet per second in order, by lowering the grade, to effect, as far as possible, the sewerage of the entire peninsula, a few marginal areas only being excluded.

Pumping Plant.

The sewage collected by means of these several interceptors will be delivered at a pumping station, to be located at or near the intersection of Leadenhall and Stockholm streets, as contemplated in Project C, with a level of invert 14.12 feet below mean low tide.

Here must be provided a pumping plant, which at first need be adequate only to the work contemplated at first installation.

This will require the daily disposal of 28 million gallons of sewage, which must be lifted by the pumps from the level of 10 feet below mean low tide to a height of 52 feet above the same datum, involving a total maximum resistance equivalent to about 112 feet of head.

As one-half of the sewage must be provided for in eight hours, the pumping plant must have a capacity sufficient to lift 42 million gallons per day against this head.

To meet this service the estimates provide four 500 horse-power boilers and three 25 million gallon pumps, with two 3 million gallon pumps to dispose of the ground water, which will be separately collected and discharged directly into the river.

Outfall Main.

To carry the amount of sewage collected at first installation to the filtration fields, but one outfall main of 56 inches diameter is requisite Nevertheless, it is deemed a proper measure of economy in effecting the costly crossing of the Patapsco River to lay down at once under the river three of the five outfall mains which will be ultimately required, and on this basis the estimates have been developed.

The revised line for the outfall mains follows the course suggested by the Consulting Engineers for Project C to near the city end of the Long Bridge at the foot of Byrd street.

Thence the line deviates from the former course, and, passing under the river by a shorter length of submerged main than by Project C,

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reaches the Anne Arundel shore at a point about 2,200 feet, as measured along the shore, to the eastward of the bridge terminus. From the shore the line continues past the village of Masonville with a gradual rise along the eastern slope of the ridge, which in Project C was traversed by tunnel, and passing southerly through the village of South Baltimore reaches a point near the banks of Cabin Creek, whence, if required by future extension of the filtration project, a main will lead off in a southeasterly direction to Marley Neck.

From this point of divergence the outfall main will continue on its ascending grade, passing under Cabin Creek, and will make a junction with the original line of Project C, at a point on that line about three miles south of the Long Bridge, whence it continues very nearly on the original line to the Glen Burnie filtration fields.

Here ample provision should be made for possible needs, and the estimate of land required, some 1,800 acres, is substantially the same as that recommended for this locality by the Consulting Engineers in their estimates for Project C.

Completed Work.

Low-Level Service.

This will provide for a population of 600,000, and the required interceptors are already described under the head of first installation, p. 43.

High-Level Service.

The High-Level Interceptors discharge into gravity mains at a slightly lower elevation than in Project C, and hence may terminate at a point on Eutaw street, opposite Eutaw Court, or 180 feet south of the centre of Franklin street.

The Western High-Level Interceptor.

Beginning at Baltimore street and Calverton road, to which point is brought the sewage from all the territory to the north lying east of Gwynn's Falls, the Western High-Level Interceptor follows the latter road with a diameter of 4 feet 3 inches to Frederick avenue, to Pulaski street, to Pratt street, to Fulton avenue, to Lemmon street, to Mount street, to Hollins street, to Gilmor street, to Fayette street, to Calhoun street, to Lexington street, to Carey street and to Mulberry street. At this point the diameter is increased to 4 feet 9 inches and the line continues along Mulberry street, Schroeder street, Milton Place, Fremont

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EASTERN HIGH LEVEL INTERCEPTOR

EASTERN LOW LEVEL INTERCEPTOR

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avenue, Bradley street, Brune street, George street, Clinton avenue, Myrtle avenue and Hoffman street to Argyle avenue. Here the diameter is again increased to 5 feet 3 inches and the line passes by Argyle avenue, Biddle street and Druid Hill avenue to Eutaw street, where, at Ross street, it is joined by the Eastern High-Level Interceptor and a diameter of 7 feet 6 inches is required to its terminus opposite Eutaw Court.

The Eastern High-Level Interceptor.

On account of the reduced capacity required, the revised interceptors have smaller diameters and steeper gradients than those in Project C, and for this reason the eastern end of the Eastern High-Level Interceptor has been located on higher ground than in that project.

Beginning on North avenue, at Hopkins avenue, with a diameter of 18 inches, it runs westerly to Broadway, and thence through Broadway, Townsend street, Caroline street, Lanvale street, Spring street, Oliver street, Eden street, Hoffman street and Ensor street to Twentieth street. Here it receives considerable sewage from the valley of Jenkins' Run, and continues on Twentieth street and under Jenkins' Run in a siphon of two 16-inch cast-iron pipes, and then in the same street in a 3-foot 3-inch sewer to Barclay street, to North avenue, to the line of Hargrove alley, through the grounds of the Blind Asylum and Hargrove alley to Twenty-first street. Here a diameter of 4 feet is required, and this is maintained along the latter street to Jefferson Place. At this point the interceptor receives the sewage from the territory lying between Jones' Falls and Waverly, and is carried by a siphon consisting of two 24-inch cast-iron pipes, laid in a brick-lined tunnel under the valley of Jones' Falls, to a point near North avenue and McMechen street. From this point it follows McMechen street with a diameter of 5 feet to the west side of Mt. Royal avenue, where it is again enlarged to a diameter of 5 feet 9 inches, and runs on Mt. Royal avenue, Lanvale street, Rutter alley, Dolphin street and Park avenue to Camel alley. Thence it continues with a diameter of 6 feet on Park avenue, Monument, Howard and Ross streets to Eutaw street, where it joins the Western High-Level Interceptor, as described.

The velocity in the Western High-Level Interceptor, when running half full, will be 4 feet per second throughout. In the Eastern High-Level Interceptor a velocity of 3½ feet per second is obtained for that portion lying west of Jones' Falls, while for the balance the velocity has been reduced to 3 feet per second to avoid an increased length of siphon under Jenkins' Run, and in order to include as much territory as practicable in the high-level system. A reduction of velocity on the West-

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ern High Level Interceptor did not appear advisable, because the greater slope of the ground in its vicinity would have rendered any considerable increase of available drainage by a change of sewer gradients impossible.

The high level sewage collected from a population of 400,000 is estimated to average 39,200,000 gallons per day when the works are complete, and it will be delivered by two 56-inch steel gravity mains to the Glen Burnie filtration fields.

Pumping Plant.

On the completion of the work the low level interceptors will deliver on an average 78 million gallons, and a maximum of 84 million gallons of sewage per day to the pumps. The latter must, however, be of capacity to take sewage at times of greatest flow, or at a rate of 126 million gallons per day, and pump it as shown below:

Destination.	Maximum Rate of Flow.	Lift in Feet.
Marley.....	42,000,000 gals. per day.	110
Elvaton.....	42,000,000 " "	131
Elvaton.....	42,000,000 " "	144

For this service five 25 million gallon pumps are required, which, with one in additon to provide for contingencies and two 3 million gallon pumps for ground water, give a total capacity of 156 million gallons per day.

To provide the power for this work six 500 horse-power boilers will be required which, with two held in reserve for repairs and contingencies, will supply a total of 4,000 horse-power.

Lines of Outfall Mains.

There will be ultimately required five outfall mains 56 inches in diameter, of which three will serve a population of 600,000 in the low-level districts and two a population of 400,000 in the high-level districts.

The Low-Level Outfall Mains.

All the low-level mains follow the line described on p. 45 for the first installation from the pumping station to a point near Cabin Creek, where the first will diverge in a southeasterly direction, and passing first under Cabin Creek and then under Curtis Creek by inverted siphons, will continue to a point on Marley Neck, near the Marley Road, which is of sufficient elevation—57 feet above datum—to permit the irrigation of some 1,080 acres. It is designed to carry 40 million gallons per day.

The second and third low-level mains follow the line described for first installation to the Glen Burnie fields and continue beyond, crossing

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Marley Creek and terminating, respectively, 2,600 and 3,600 feet beyond the cross roads at Marley. The first will deliver 22 million gallons per day at elevation 55; and the second 22 million gallons per day at elevation 66.

Of these 44 million gallons, 8 million will be utilized on the Glen Burnie fields and 36 million will irrigate some 720 acres at Elvaton.

The High-Level Outfall Mains.

The two high-level mains will take the sewage collected by the high-level interceptors at Eutaw street, near Franklin, to the Glen Burnie fields on lines as described for the low-level main for first installation, delivering at elevations 52 feet and 46 feet, respectively, above mean low-tide. They will together carry 42 million gallons per day, which, with the 8 million gallons delivered from the low-level main, will irrigate 1,380 acres of land.

PROJECT D—AGRICULTURAL FILTRATION.

ESTIMATES OF COST.

A.—Summaries for Construction.

a. For First Installation.

Land to be acquired for filtration at Glen Burnie	$186,000 00	
Preparing thereof 720 acres	747,324 00	
Building and utensils for four stations	26,667 00	
Force mains	793,276 00	
Right of way	15,000 00	
Pumping station at Stockholm and Leadenhall streets	235,800 00	
Pumping machinery, three 25,000,000 gallon pumps and two 3,000,000 gallon pumps	278,000 00	
Boilers, four 500 horse-power	32,000 00	
Eastern Low-Level Interceptor, west of Harris Creek	552,760 00	
Western Low-Level Interceptor, east of Ostend street	61,677 00	
Locust Point Interceptor, west of Race street	49,423 00	
York Street Interceptor, north of Hughes avenue	10,191 00	
	$2,988,118 00	
Add for district main sewers	200,000 00	
		$3,188,118 00

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b. For Completed Work, to serve a population of one million.

Land to be acquired for filtration	$344,000 00	
Preparing 2,765 acres	2,869,932 00	
Buildings and utensils for fourteen stations	93,333 00	
Force and gravity mains	3,588,594 00	
Right of way	25,000 00	
Pumping station at Stockholm and Leadenhall streets	262,000 00	
Pumping machinery, six 25,000,000 gallon pumps and two 3,000,000 gallon pumps	548,000 00	
Boilers, eight 500 horse-power	64,000 00	
Eastern Low-Level Interceptor	588,665 00	
Western Low-Level Interceptor	133,014 00	
Eastern High-Level Interceptor	265,390 00	
Western High-Level Interceptor	174,516 00	
Locust Point Interceptor	178,566 00	
York Street Interceptor	25,231 00	
	$9,160,241 00	
Add for district main sewers	700,000 00	
Total		$9,860,241 00

B.—Summaries for Annual Maintenance, Interest and Renewals.

a. For First Installation:

Interest on first cost, including payment to sinking fund, $3,188,118.00 @ 4%			$127,524 72
Depreciation and renewals:			
On interceptors, reticulation and district mains, $2,374,051 @ ½%		$11,870 26	
On buildings, pumping station, etc., $262,467 @ 1%		2,624 67	
On discharge mains, $793,276 @ 3%		23,798 28	
On pumping machinery, $278,000 @ 4%		11,120 00	
On boilers, $32,000 @ 5%		1,600 00	
On siphons, $33,409 @ 3%		1,002 27	
			$52,015 48
Operation:			
Cost of pumping:			
Per day:			
Wages	$18 75		
Oil and waste	2 50		
Coal, 12 net tons @ $2.50	30 00		
	$51 25		
Add 10% for contingencies	5 13		
365 days @	$56 38	$20,578 70	
Carried forward		$20,578 70	$179,540 20

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Brought forward		$20,578 70	$179,540 20
Cleaning and inspection of interceptors and district mains		1,700 00	
Cleaning and inspection of reticulation system.		15,000 00	
Operation of filtration fields and cleaning discharge mains		25,852 00	
Superintendent		1,500 00	
			$64,630 70
Total			$244,170 90
b. For Completed Work:			
Interest on first cost, including payment to sinking fund, $9,860,241 @ 4%			$394,409 64
Depreciation and renewals:			
On interceptors, district mains and reticulation, $6,645,382 @ ½%		$33,226 91	
On pumping station, buildings, etc., $355,333 @ 1%		3,553 33	
On discharge mains, $3,588,594 @ 3%		107,657 82	
On pumping machinery, $548,000 @ 4%		21,920 00	
On boilers, $64,000 @ 5%		3,200 00	
On siphons, $122,174 @ 3%		3,665 22	
			$173,223 28
Operation:			
Cost of pumping:			
Per day:			
Wages	$40 50		
Oil and waste	5 00		
Coal, 42 net tons @ $2 50	105 00		
	$150 50		
Add 10% for contingencies	15 05		
365 days @	$165 55	$60,425 75	
Cleaning and inspection of interceptors and district mains		3,000 00	
Cleaning and inspection of reticulation system.		45,800 00	
Operation of filtration fields and cleaning discharge mains		100,324 00	
Superintendents, 3 @ $1,500 00		4,500 00	
			$214,049 75
Total			$781,682 67

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APPENDIX C.

PROJECT D-E.

A project termed E has been worked out contemplating the delivery of the sewage at treatment works in the vicinity of Masonville, Anne Arundel county. Under this plan the high-level sewage, amounting on an average to about 66 million gallons per day from a forecast population of 633,000 persons, would be collected at Eutaw and Camden streets, from which point it would flow by gravity through three 56-inch steel mains to the treatment works.

The low-level sewage, amounting to an average of about 51 million gallons per day from a population forecast at 367,000 persons, would be collected, as in Project D, at a pumping station near the intersection of Stockholm and Leadenhall streets, from which point it would be pumped through two 56-inch steel discharge mains to the above treatment works.

This project, as a whole, is not recommended for reasons given on page 22, but, should treatment of sewage at Masonville be found desirable in the future, there would be an economy resulting from a combination of Projects D and E, as referred to on page 24, and described below as Project D-E.

First Installation.

The first installation of Project D-E is identical with that of Project D, described in Appendix B.

Completed Work.

Interceptors.

For the completed work the low-level interceptors and the Western High-Level Interceptor are identical with those described in Appendix B for Project D. The Eastern High-Level Interceptor would, however, be lowered to deliver as much sewage as possible by gravity at Masonville.

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The Eastern High-Level Interceptor (Plate V) begins at Fairmount avenue and Chapel street with a diameter of 12 inches. It follows Fairmount avenue to Bethel street, where it is given a diameter of 2 feet 9 inches to Madison street, to the west side of Broadway and to Ashland avenue. Here, in order to avoid a long detour up the valley of Harford Run, the latter is crossed on Ashland avenue by a siphon, consisting of two 24-inch cast-iron pipes, and at Caroline street passes over the drain which runs on Ashland avenue, between Bond street and Caroline street. The siphon extends to Central avenue, whence the line continues as a 4-foot sewer; thence on Ashland avenue to Neighbor street, to Homewood avenue, to Eager street and to Concord street. Here a shaft leads to an inverted siphon, consisting of two 36-inch steel pipes, laid in a tunnel under Jones' Falls, to a second shaft located 100 feet east of Hunter alley. At this point the sewage rises to the interceptor, 6 feet 6 inches in diameter, as far as Hunter alley; thence 7 feet 3 inches in diameter, still in Eager street, to Calvert; in Calvert to Madison, requiring at Read street a modification of the drain in that street; in Madison street to St. Paul street, and in St. Paul street to 100 feet north of Centre street. Here, to retain sufficient cover, the section must be modified, or the single interceptor may be changed to two lines of 40-inch cast-iron pipe with their inverts connecting the inverts of the brick sewers above and below. One hundred feet south of Centre street, a single conduit, 7 feet 6 inches in diameter, is resumed, which continues to Fayette street, and on Fayette street to Howard street. At Park avenue the present drain will require re-location. The interceptor then extends on the east side of Howard street to Cider alley. Here, to obtain cover, the top is depressed, and the interceptor crosses over the Belt Line tunnel. It continues thence in Cider alley and Eutaw street to the inlet of the gravity discharge mains at Camden street, with so steep a gradient that the diameter is reduced to 4 feet 4 inches. The velocity, when running half full, is 3½ feet per second as far as the tunnel crossing, below which it is 11 feet per second. This velocity must be considered in the design and materials of this section of the interceptor.

Pumping Plant.

The low-level sewage reaching the pumping station will, by this arrangement, eventually reach a maximum of 66 million gallons per day, and the pumps will require a capacity to lift this at the rate of 98 million gallons per day, at periods of maximum discharge, through a vertical height of 40 feet. For this the boilers and engine power supplied for first installation will be ample, but the pumping capacity will have to be increased to about 125 million gallons per day.

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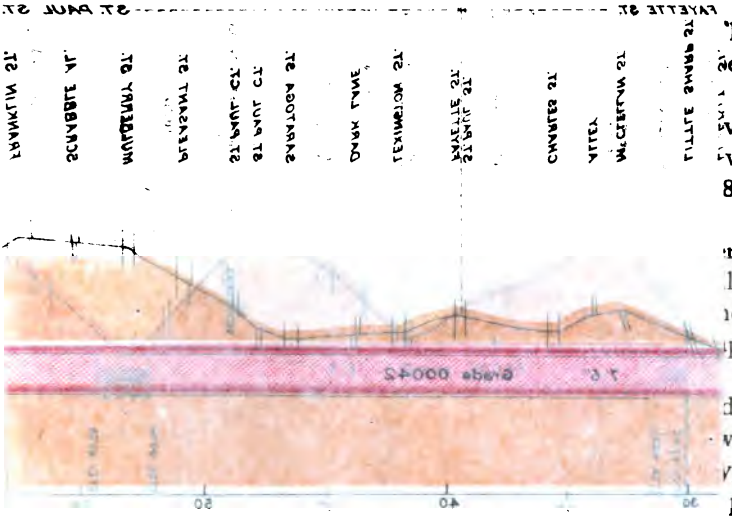

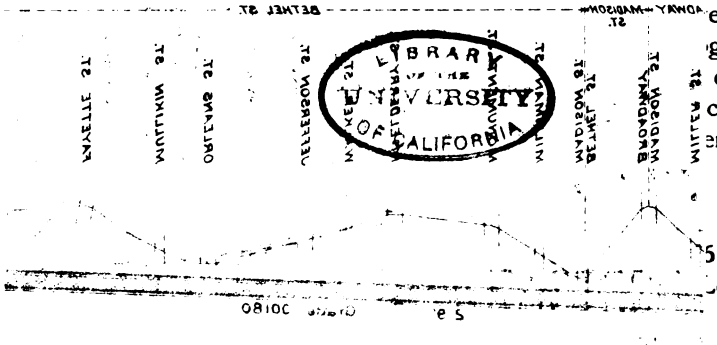

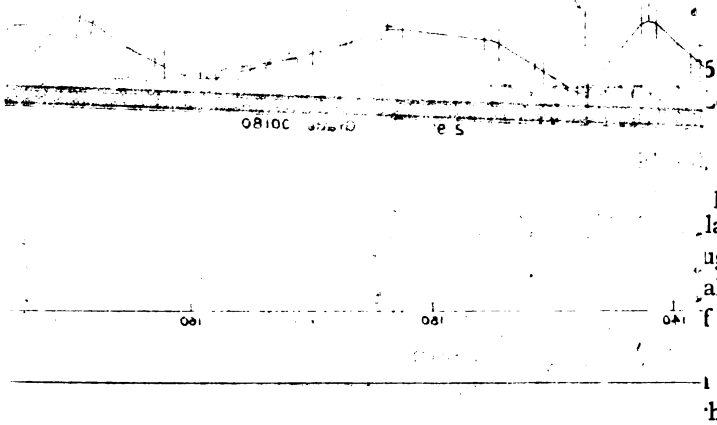

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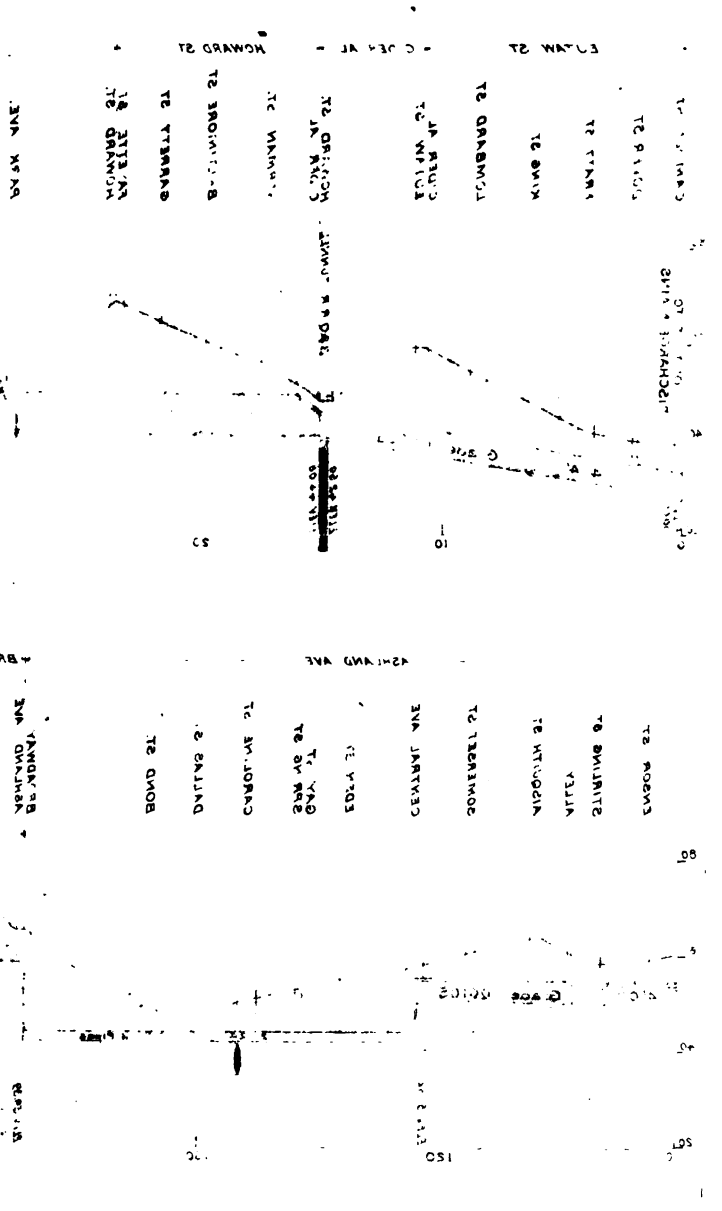

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Outfall Mains.

There will be required five 56-inch steel outfall mains. The main originally laid from the pumping station to Glen Burnie will be disconnected from the pumps and extended up Eutaw street to near Franklin street, where it will receive the sewage from the Western High-Level Interceptor, amounting to some 19 million gallons per day, and convey it by gravity to the Glen Burnie fields at a maximum rate of about 28 million gallons per day.

Two gravity mains will extend from the terminus of the Eastern High-Level Interceptor, at Eutaw and Camden streets, to Masonville. The sewage collected by the Eastern High-Level Interceptor amounts to a maximum of about 34 million gallons per day, requiring a capacity of pipes equal to 51 million gallons per day.

Two more mains will take low-level sewage exclusively, and extend from the pumping station to Masonville. The low-level sewage has been stated as amounting at times to 66 million gallons per day, requiring provision at times of maximum flow for 98 million gallons per day.

Now, with the assumed hydraulic gradient of 0.11 per cent., these two mains will carry but about 81 million gallons per day, leaving a deficit in capacity of pipes of some 17 million gallons per day. We have, however, in the two pipes leading from the Eastern High-Level Interceptor, an hydraulic gradient of 0.081 per cent., furnishing together a capacity of 71 million gallons per day; but as the required capacity is but 51 million gallons per day, there will be an excess in capacity, which may be utilized by pumping, when found necessary, the remaining 17 million gallons of low-level sewage into one of these mains.

Treatment of Sewage.

The maximum volume of sewage to be disposed of is 126 million gallons per day. Of this, 19 million from the Western High-Level Interceptor will flow by gravity to the Glen Burnie fields, leaving 107 million gallons to be delivered at Masonville for treatment.

It has been recommended to defer decision in regard to the possible use of a treatment plant at this point until after the first installation is effected, under the plans of Project D. By this time, it is thought, accumulated experience in the use of the new methods of bacterial purification will suffice to demonstrate what particular method, if any, is most likely to meet efficiently the requirements of Baltimore.

The acreage necessary for the daily treatment of 107 million gallons of sewage by any of the methods may be had in the neighborhood of Masonville, and an approximate estimate of the cost of establishing a plant has been made on the basis of recorded experience abroad.

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PROJECT D-E—AGRICULTURAL FILTRATION COMBINED WITH SPECIAL TREATMENT.

ESTIMATES OF COST.

SUMMARIES FOR CONSTRUCTION.

a. **First Installation, for a population of 200,000.**

Estimate as for Project D		$3,188,118 00

b. **Completed Work, for a population of 1,000,000.**

Land for disposal	$186,000 00	
Preparation of filtration fields	747,324 00	
Land for treatment	70,000 00	
Preparation of filter beds	1,075,000 00	
Buildings and utensils	36,667 00	
Force and gravity mains, gates, branches, etc.	1,798,291 00	
Right of way	15,000 00	
Pumping station at Stockholm and Leadenhall streets	235,800 00	
Pumping machinery	350,000 00	
Boilers	32,000 00	
Low-Level Interceptors (D)	925,476 00	
Western High-Level Interceptor (D)	174,516 00	
Eastern High-Level Interceptor (E)	253,914 00	
	$5,899,988 00	
Add for District Main Sewers	700,000 00	
Total		$6,599,988 00

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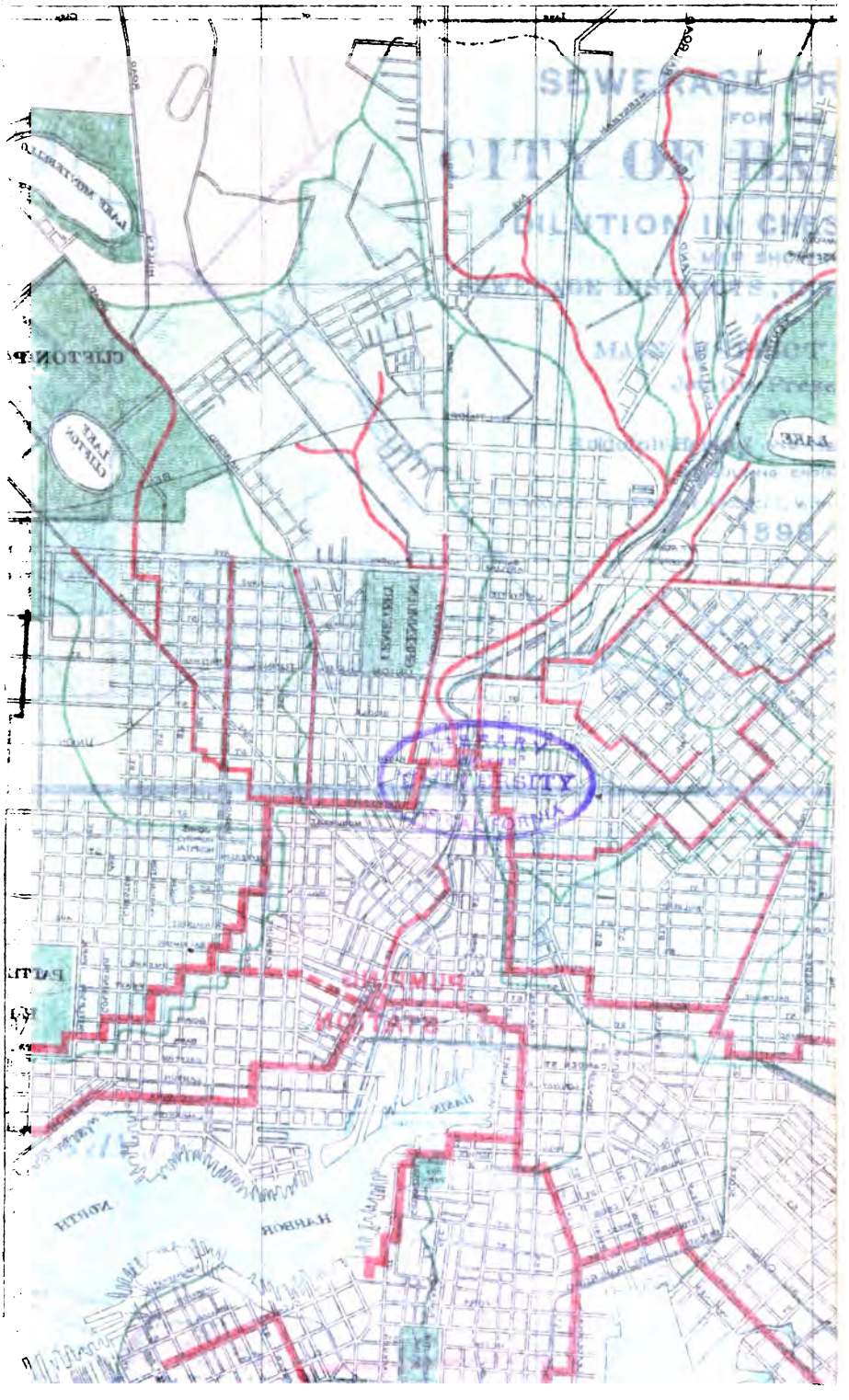

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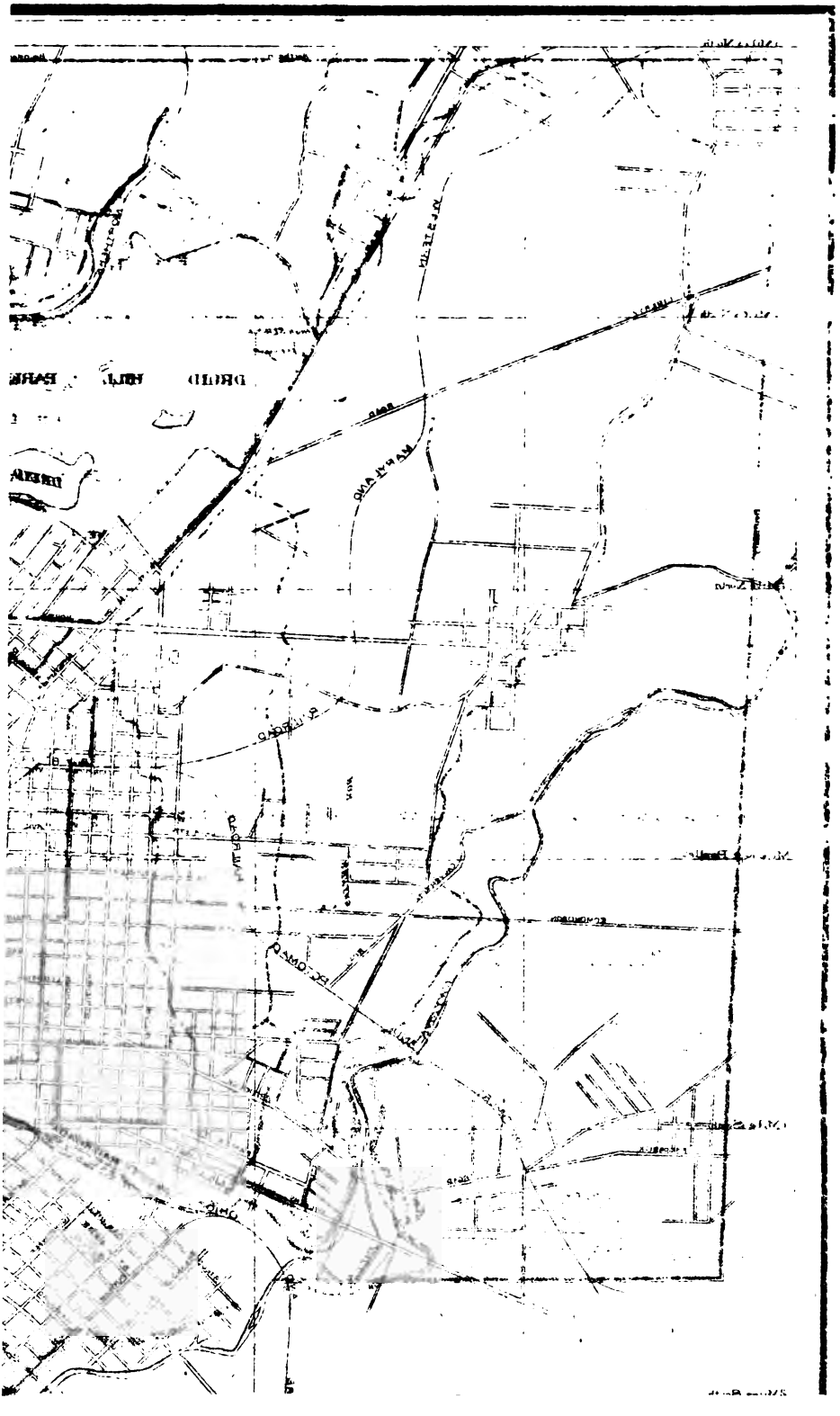

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APPENDIX D.

PROJECT L.

Project L is, in its essential features, identical with Projects A and K of the Commission's report of September 20, 1897, but modified in accordance with the diminished volume of sewage.

Plates II., VI., VII. and VIII. of the present report will serve to illustrate it sufficiently as now presented.

First Installation.

Eastern Low-Level Interceptor.

The Eastern Low-Level Interceptor runs along Glover alley from Canton street, to Foster avenue, to Luzerne street, to Hudson street, to Boston street, to Aliceanna street, to Caroline street, to Eastern avenue, to Albemarle street, to Lombard street, and along Front street to the pumping station.

Western Low-Level Interceptor.

The Western Low-Level Interceptor runs northeasterly from Putnam street on Russell, where it may, if required, collect the sewage from a considerable territory lying beyond the present city limits. Russell street for three or four blocks is as yet but a marsh, and will have to be raised several feet. The interceptor then passes under the Bush Street Drain in a siphon of two cast-iron pipes, and then under the Alluvion Street Drain to Stockholm street, to Leadenhall, to Montgomery, to Charles, to Balderston, to Light, to Lombard, to Calvert, to Water street and under Jones' Falls in two steel pipes to the pumping station. For first installation the construction on Russell street west of Ostend may be deferred, and is not included in the estimate.

Locust Point and York Street Interceptors.

Two interceptors from Locust Point will enter the Western Low-Level Interceptor—one at Stockholm and Leadenhall streets and one at York

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street. The former will collect the sewage from the greater part of Locust Point, and is located on Clemént, Allen, Winder, Race, Barney and Leadenhall streets to Stockholm street.

The York Street Interceptor drains a narrow district to the northeast of a line between Federal Hill and Riverside Park, and is located on Belt, Rupert, Montgomery and Covington streets, Hughes and Battery avenues, and York street to Charles street.

The construction of that portion of the Locust Point Interceptor lying beyond the intersection of Barney and Race streets, and that of the York Street Interceptor beyond Hughes and Battery avenues, may be deferred until after first installation, and are not included in the estimate.

Force-Main.

The sewage brought by the Low-Level Interceptors to the pumping station on the east side of Jones' Falls, a short distance north of Lombard street, is pumped thence in a 48-inch cast-iron force-main laid in the bed of Lombard street to Broadway, where it is delivered to the High-Level Interceptor.

High-Level Interceptor.

For first installation the High-Level Interceptor begins at Broadway and Lombard streets, and runs thence easterly to Ann street, to Pratt street, to Chapel street, to Gough street, to Duncan alley, to Bank street, to Patterson Park avenue, to Eastern avenue and easterly on the same, diverging into an embankment in the south side of Patterson Park, to Streeper street. Here it turns to the south and, in order to keep under cover, the grade of Eastern avenue will have to be slightly raised at this point. At Fait avenue it runs eastward to Patuxent street, then to Hudson, to Potomac, to Dillon and to the eastern city boundary.

Outfall Sewer and Submerged Outlet.

From this point the Outfall Sewer continues in a general southeasterly direction to the shores of Chesapeake Bay, crossing Bear Creek by a submerged siphon, a total distance of 11.23 miles. It is 11 feet 6 inches in diameter, and is designed to take the maximum discharge from the forecast population of one million when running two-thirds full; and its gradient will ensure a uniform velocity when half full of four feet per second. These conditions, with the elevation at outlet for a free discharge of the sewage, are elements which control the area of the city which may be served by the High-Level Interceptor without pumping.

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At the upper end of the outfall sewer a settling chamber will arrest any sand, gravel, etc., brought from above, while at the lower end the sewage will pass through a gate-house to a 66-inch submerged outlet pipe extending, at first installation, 5,000 feet out into the bay.

The sewage thus disposed of will amount at first installation to a maximum daily flow of 20 million gallons per day from 144,000 persons in the low-level districts, and of 6 million gallons per day from 56,000 persons in the adjacent high-level districts.

Pumping Plant.

The sewage will be delivered by the low-level interceptors at the pumping station, near Lombard and Front streets, and will there be lifted against a hydraulic head of about 54 feet through the force main to the High-Level Interceptor at Broadway and Lombard street.

As one-half of the sewage must be provided for in 8 hours, the pumping plant must have a capacity sufficient to lift 30 million gallons per day against this head.

To meet this service the estimates provide three 160 horse-power boilers and three 15 million gallon pumps, with two 3 million gallon pumps to dispose of the ground-water, which will be separately collected and discharged directly into Jones' Falls.

Completed Work.

Low-Level Interceptors.

The Low-Level Interceptors, which have already been described under the head of First Installation, will provide for a population of 215,000.

High-Level Interceptor.

The Main or High-Level Interceptor collects the sewage from that portion of the city lying above or to the north of it, and, with the Outfall Sewer, conveys it to the submerged outlets in Chesapeake Bay by gravity.

The entire sewage of the valleys of Gwynn's Falls and Gwynn's Run lying to the north will be collected at the intersection of Wilkens avenue and Bentalou street, from which point the interceptor is projected southeasterly to the Baltimore and Ohio Railroad property, thence parallel to the same to Calhoun street, in Calhoun to Hollins street, to Carey, to Lombard, and under the Calhoun Street and Carey Street Drains, to effect which a modified section may be required. It continues in Lombard to Schroeder, Pratt, Scott and Lombard streets, and up Fre-

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mont avenue to German street. Here it passes in a siphon of two cast-iron pipes under the Pine Street and Arch Street Drains near their junction at Penn street, over the Baltimore and Ohio Railroad tunnel, which is just cleared at German and Howard streets, up the latter to Fayette street, and eastward in that street. At Park avenue the Liberty Street Drain, 4 feet 6 inches in diameter, will have to be carried under the sewer. Continuing in Fayette street to St. Paul street, it turns northerly into the latter, whence it continues to Madison street, to Calvert street, to Eager street, to Guilford avenue, thence northerly about 200 feet, thence easterly, and, dropping by a shaft to a lower level, it extends as a siphon of two steel pipes laid in a tunnel under Jones' Falls. On the eastern side of the Falls it rises again and runs south to Eager street, thence to Forrest street, to Madison street and to Caroline street. At Eden street, where the Central Avenue Drain is crossed, a re-location of the latter may be necessary. The line continues southerly on Caroline street to Mullikin street, to Bond street, to Fairmount avenue, to Bethel street, to Baltimore street, to Broadway and to Lombard street. Here it receives the low-level sewage, and continues as already described for first installation. The high-level service will serve a population of 785,000.

Pumping Plant.

On the completion of the work the low-level interceptors will deliver on an average 28 million gallons and a maximum of 30 million gallons of sewage per day to the pumps. The latter must, however, be of capacity to take the sewage at times of greatest flow, or at a rate of 45 million gallons per day, and pump it with a lift of about 54 feet to the high-level interceptor.

For this service three 15 million gallon pumps are required, which, with one in addition to provide for contingencies and two 3 million gallon pumps for ground-water, give a total capacity of 66 million gallons per day.

To provide the power for this work three 160 horse-power boilers will be required, which, with one held in reserve for repairs and contingencies, will supply a total of 640 horse-power.

Outfall Sewer and Submerged Outlets.

The Outfall Sewer to the Chesapeake Bay provided for first installation will serve for the completed work without additional cost, but a second submerged 66-inch main will become necessary, which is estimated for, to extend from the shore to the point marked K in Plate II, about $2\frac{4}{10}$

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HIGH LEVEL INTERCEPTOR

WESTERN LOW LEVEL INTERCEPTOR

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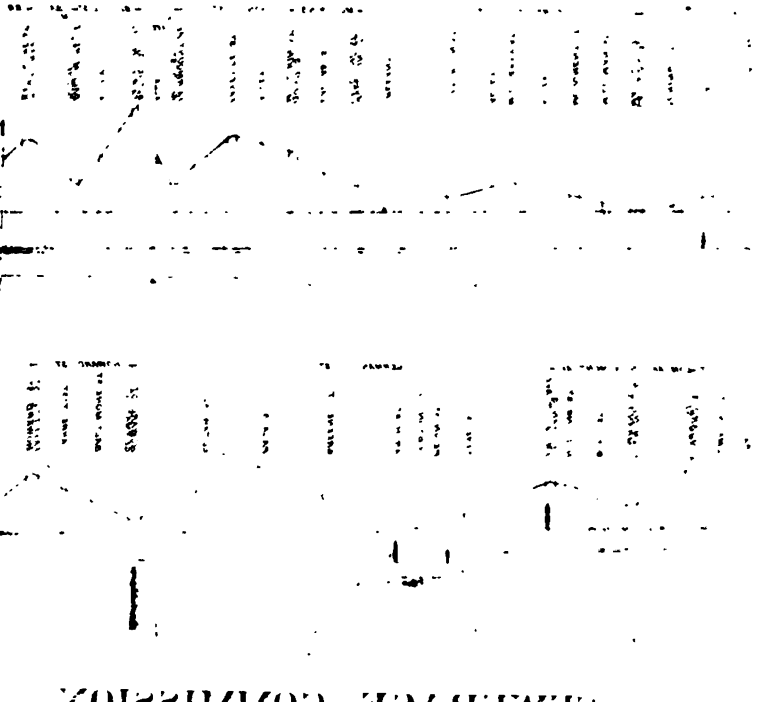

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miles east of Rear Range Light. At the same time it may be deemed expedient to extend the first submerged main to about the same distance from shore. The cost of effecting this is also included in the estimates.

PROJECT L—DILUTION.

ESTIMATES OF COST.

A—Summaries for Construction.

a. For First Installation:

Pumping station near Front and Lombard streets.	$69,880 00	
Pumping machinery, three 15,000,000 gallon pumps and two 3,000,000 gallon pumps	120,500 00	
Boilers, three 160 horse-power.	7,680 00	
Force main, 3,630 feet of 48-inch cast-iron pipe..	39,950 00	
High-Level Interceptor, east of Broadway.....	344,332 00	
Low-Level Interceptor, east of Russell street....	349,535 00	
Locust Point Interceptor, west of Race street....	49,423 00	
York Street Interceptor, north of Hughes avenue.	10,191 00	
Outfall Sewer, City boundary to Chesapeake Bay.	1,698,855 00	
Right of way, City boundary to Chesapeake Bay.	25,000 00	
One 66-inch submerged outlet pipe in the Bay, 5,000 feet in length.....	287,500 00	
	$3,002,846 00	
Add for District Main Sewers.....	200,000 00	
Total.....		$3,202,846 00

b. For Completed Work, to serve a population of one million.

Pumping station near Front and Lombard streets.	$69,880 00	
Pumping machinery, four 15,000,000 gallon pumps and two 3,000,000 gallon pumps.....	158,000 00	
Boilers, four 160 horse-power.....	10,240 00	
Force main, 3,630 feet of 48-inch cast-iron pipe..	39,950 00	
Interceptors	1,594,906 00	
Outfall Sewer, City boundary to Chesapeake Bay.	1,698,855 00	
Right of way, City boundary to Chesapeake Bay.	25,000 00	
Two 66-inch submerged outlet pipes in the Bay, 11,100 feet in length.....	1,276,500 00	
	$4,873,331 00	
Add for District Main Sewers.....	700,000 00	
Total.....		$5,573,331 00

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B.—Summaries for Annual Maintenance, Interest and Renewals.

a. For First Installation:

Interest on first cost, including payment to sinking fund, $3,202,846 @ 4%		$128,113 84
Depreciation and renewals:		
On interceptors, out-fall sewer, reticulation and district mains, $4,152,336 @ ½%	$20,761 68	
On submerged outlet and pumping station, $357,380 @ 1%	3,573 80	
On force main, $39,950 @ 3%	1,198 50	
On pumping machinery, $120,500 @ 4%	4,820 00	
On boilers, $7,680 @ 5%	384 00	
On siphons, $88,985 @ 3%	2,669 55	
		$33,407 53
Operation:		
Cost of pumping:		
Per day:		
Wages	$17 75	
Oil and waste	2 00	
Coal, 7.0 net tons @ $2.50	17 50	
	37 25	
10%	3 73	
365 days @	$40 98	$14,957 70
Cleaning and inspection of interceptors and district mains		2,075 00
Cleaning and inspection of reticulation system		15,000 00
Cleaning and inspection of outfall, 5 men @ $625 00		3,125 00
Superintendent		1,500 00
		$36,657 70
Total		$198,179 07

b. For Completed Work:

Interest on first cost, including payment to sinking fund, $5,573,331 00 @ 4%		$222,933 24
Depreciation and renewals:		
On reticulation, interceptors, outfall sewer and district mains, $8,573,761 @ ½%	$42,868 81	
On submerged outlet and pumping station, $1,346,380 @ 1%	13,463 80	
On force main, $39,950 @ 3%	1,198 50	
On pumping machinery, $158,000 00 @ 4%	6,320 00	
On boilers, $10,240 @ 5%	512 00	
On siphons, $99,053 @ 3%	2,971 59	
		67,334 70
Carried forward		$290,267 94

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Brought forward			$290,267 94
Operation:			
Cost of pumping:			
Per day:			
Wages	$20 25		
Oil and Waste	2 75		
Coal, 8.5 net tons @ $2 50	21 25		
	$44 25		
10%	4 43		
365 days @	$48 68	$17,768 20	
Cleaning and inspection of interceptors, and district mains		3,000 00	
Cleaning and inspection of reticulation system		45,800 00	
Cleaning and inspection of outfall, 5 men @ $625 00		3,125 00	
Superintendent		1,500 00	
			71,193 20
Total			$361,461 14

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SEWERAGE COMMISSION
OF THE
CITY OF BALTIMORE

PROFILE AND SECTIONS
OF
OUTFALL SEWER AND BEAR CREEK SIPHON
DILUTION PROJECT
1899

PROFILE ON LINE OF
Horizontal
Vertical

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APPENDIX E.

PROJECT L-M.

As has been mentioned on page 27, if it should be found desirable to treat the sewage before delivery into the bay by Project L, the necessary works can be built advantageously in the vicinity of the shores of the bay. The cost of such a plan has been estimated and is hereby presented as Project L-M.

First Installation.

The first installation of Project L-M is identical with that of Project L, which is already described on page 57.

Completed Work.

The completed work of Project L-M is identical with that of Project L to a point near the shores of the bay.

Here, instead of continuing to and under the waters of the bay by submerged outlet mains, the sewage would be directed to a bacterial treatment plant for which adequate ground can be located without difficulty, and at much less cost than at Masonville.

PROJECT L-M.—DILUTION COMBINED WITH SPECIAL TREATMENT.

ESTIMATES OF COST.

Summaries of Construction.

a. First Installation, for a population of 200,000.

Estimated cost the same as for Project L..... $3,202,846 00

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b. **Completed Work, for one million persons.**

Pumping station near Front and Lombard streets	$69,880 00	
Pumping machinery	158,000 00	
Boilers	10,240 00	
Force main	39,950 00	
Interceptors	1,594,906 00	
Outfall sewer	1,698,855 00	
Right of way	25,000 00	
One 66-inch submerged outlet pipe 5,000 feet in length	287,500 00	
Land for treatment	16,000 00	
Preparation of bacterial filters	1,250,000 00	
House, utensils, etc	10,000 00	
	$5,160,331 00	
Add for district main sewers	700,000 00	
Total		$5,860,331 00

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APPENDIX F.

REPORT OF JAMES MANSERGH, ESQ., C.E.,

ON THE

BACTERIAL TREATMENT OF SEWAGE IN ENGLAND.

LONDON, 11th January, 1899.

To the Chairman and Members of the
Sewerage Commission of the City of Baltimore:

GENTLEMEN:

On the 11th August last your Chairman, Mendes Cohen, Esq., Past-President of the American Society of Civil Engineers, asked me by letter if I would undertake to advise you as to the bacterial treatment of sewage now much discussed in England, and after a short correspondence I agreed to do so.

My attention was requested particularly to the following processes:

(1) Dibdin's bacterial filters.
(2) Cameron's septic tank.
(3) Scott-Moncrieff's system.
(4) Lowcock's aerated bacterial filters.
(5) The Ferozone-polarite process.

And I have added a sixth to the list, viz:

(6) Ducat's self-acting bacterial filter.

My advice was requested as to the efficiency and availability of the methods of bacterial treatment now being tested and to the degree of their development. Also whether any of the methods are so successful as to warrant their application to the treatment of 40 million to 120 million Imperial gallons per day, and if not yet proved reliable for such an amount of duty, whether they are suitable for suburban districts with a sewage flow of one to two and a half million Imperial gallons per day.

In order to get the latest facts, my partner, Mr. Strachan, has specially examined Dibdin's filters at Sutton and Barking, Cameron's septic tank at Exeter and Yeovil, Lowcock's aerated bacterial filters at Wolver-

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hampton, the Ferozone-polarite process at Huddersfield and Chorley, and Ducat's self-acting filter at Hendon.

I asked Dr. Sims Woodhead, F. R. S. E., Director of the Research Laboratories of the Conjoint Board of Physicians (London) and Surgeons (England), to co-operate with me as to the bacteriological features of the processes, and I append those extracts from his report which are of especial interest.

Accompanying this report there are 5 drawings to illustrate and explain the descriptions:

(1) The Dibdin bacterial filters at Sutton.

(2) The Cameron septic tank at Exeter.

(3) Ducat's aerated filters, the polarite filters at Chorley and Lowcock's filters.

(4) A diagram showing the effect of subdivision on the rotation of the filters.

(5) A diagram showing the rotation of the filters during rain.

It will conduce to a full understanding if I divide my report into three, and I propose in the first part to set out the facts and results of each of the processes, in the second to criticise them, and in the third to add a few words as to their applicability to Baltimore.

PART I.

Dibdin's Bacterial Filters.

In the summer of 1892 the London County Council conducted a series of small experiments on the filtration of the sewage effluent from the precipitation tanks at the northern sewage works of the Metropolis at Barking, by passing it through filters containing burnt ballast, pea ballast, coke breeze, sand and polarite.

At the Barking works the crude sewage is first treated with 3.7 grains of lime and one grain of protosulphate of iron per gallon, and after passing slowly through the precipitation tanks the sewage effluent is turned into the storage chambers and then discharged into the River Thames opposite the works. The effect of the precipitation is shown by the following table, which gives the average results of a complete series of two-hour samples for the whole year 1894:

	Crude sewage. Grains per gallon.	Sewage effluent. Grains per gallon.
Total suspended matter	29.8	7.1
Total dissolved solids	60.2	63.2
Chlorine	11.1	10.8
Oxygen absorbed from permanganate in 4 hours	3.124	3.225
Free Ammonia	3.027	3.137
Albuminoid Ammonia	0.353	0.356

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Broadly speaking, there is a considerable reduction of the suspended matters, but in other respects the analyses show little difference between the crude sewage and the effluent, the process being specially designed for the removal of the suspended matters only.

The filters were each about 24 yards in area, and something less than 200,000 gallons of sewage effluent was filtered through them. The results obtained appeared to show the superiority of coke breeze as the filtering medium, and accordingly a filter having an area of one acre was made, in which fine pan breeze was placed for a depth of 3 feet and covered with a 3-inch layer of gravel as a weighting material. There were perforated drain-pipes laid on the bottom of the filter to assist in the discharge of the filtrate, which passed into a ditch and then into the river.

At the outset an attempt was made to pass one and a quarter million gallons per day through this filter, with the result that it ceased to act in about six weeks, and became putrid throughout.

It was allowed a period of rest, and at the end of 14 weeks it recovered itself and was sweet once more.

In April, 1894, it was at work again, and small quantities of sewage effluent from the precipitation tanks were put on to it at first, and were gradually increased to 500,000 gallons per day as it got into condition, which it did in about five weeks. The analytical results obtained were as under:

	Sewage effluent. Grains per gallon.	Filtrate. Grains per gallon.
(1) Oxygen absorbed in 4 hours	4.096	0.856
(2) Albuminoid Ammonia	0.416	0.095
(3) Nitrogen as Nitrates	0.1280	0.2378

The quantity per day was then increased to 600,000 gallons for three months, and the following average results were obtained:

	Sewage effluent. Grains per gallon.	Filtrate. Grains per gallon.
Oxygen absorbed in 4 hours	3.608	0.730
Albuminoid Ammonia	0.396	0.113
Nitrogen as Nitrates	0.0223	0.1414

By this time the method of working the filters to the best advantage was better understood, and the rotation of the fillings was systematized. The filter was filled to the surface in about 2 hours, the sewage effluent remained in it at rest for 1 hour, and the emptying and aerating occupied five hours, thus making a cycle of eight hours. Three cycles a day for five days a week and two on the sixth day were regularly done for eight weeks, there being a rest of 32 hours each week end. An average

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of one million gallons per day, calculated over seven days a week, was dealt with in this way, with the following average results:

	Sewage effluent.	Filtrate.
	Grains per gallon.	
Oxygen absorbed in 4 hours.....	4.113	0.935
Albuminoid Ammonia.....	0.382	0.114
Nitrogen as Nitrates.....	0.3956	0.6990

These results were obtained in the winter of 1894-5, when ice formed on the surface of the filter.

The filter is now altered and has a depth of 6 feet of coke breeze filtering material, and the under-drains have been enlarged in size and increased in number. The enlarged filter is used tidally, and has, therefore, two cycles a day. It is filled in 2½ hours, stands full two hours and drains off for 8 hours, but the time allowed is not enough for the filter to clear itself. On the 1st of December last the filter was filled once only, and after standing 2 hours was allowed to drain off for 19 hours. The valves were then shut, and 14 inches of filtrate was found on the bottom. The reduced number of cycles per day and the difficulty of emptying the filter have operated to keep the output of the 6-feet filter at practically the same quantity as the 3-feet filter. The filtrate is clear and inodorous, with a slight iron tinge.

It may be of interest to state that for three months in the spring of 1897 the crude sewage at Barking was not treated chemically. It was passed through the precipitation channels in the same manner as when the lime and iron were added, and some of the solids in suspension settled to the bottom. The 6-feet filter was used during those months for the partially clarified sewage in exactly the same manner as for the sewage effluent from the precipitation process, and with equal results.

The experience gained at Barking led Mr. Dibdin to suggest in 1896 to the Urban District Council of Sutton, in Surrey, of which body he was a member and is now Chairman, the advisability of applying the crude sewage to filters filled with coarse material, and then putting it into fine filters in the same manner as was done with the sewage effluent from the precipitation process. This idea was accepted by the Council and a portion of the sewage was dealt with. This method of dealing with sewage without the aid of chemicals or mechanical precipitation was brought to its present stage by Mr. Dibdin, and is now known as his process. He has not attempted to obtain proprietary rights in it.

Sutton is situate about 12 miles from London and is partly on the chalk and partly on London clay. It has a population of 16,000, of whom 13,000 occupy premises draining to the sewage farm. The dry weather flow of sewage is 400,000 gallons per day. No rain water

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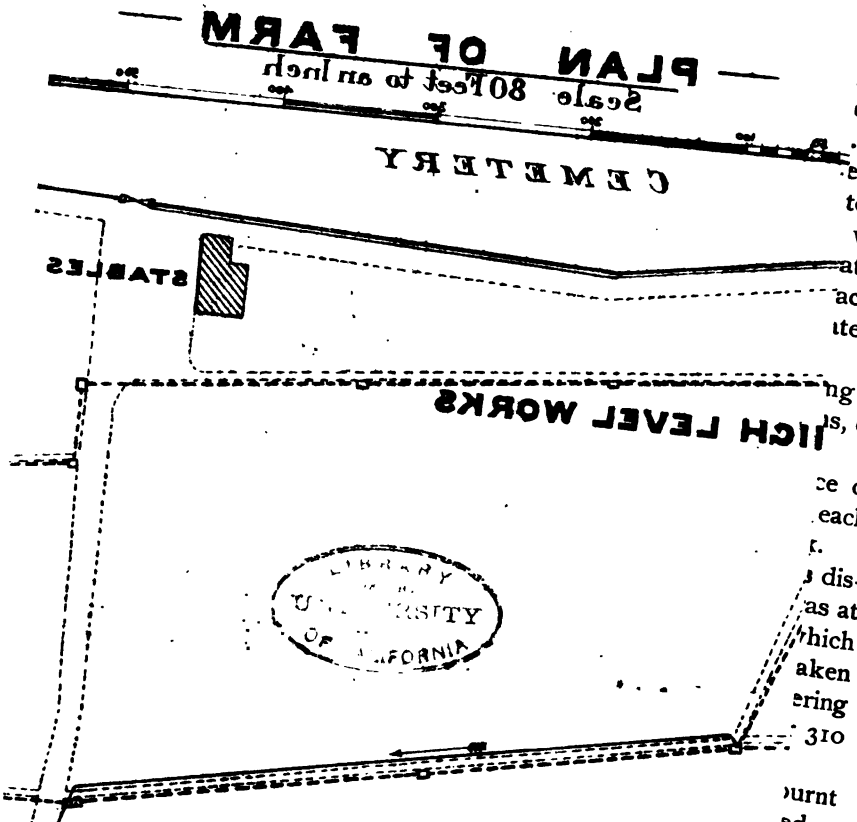

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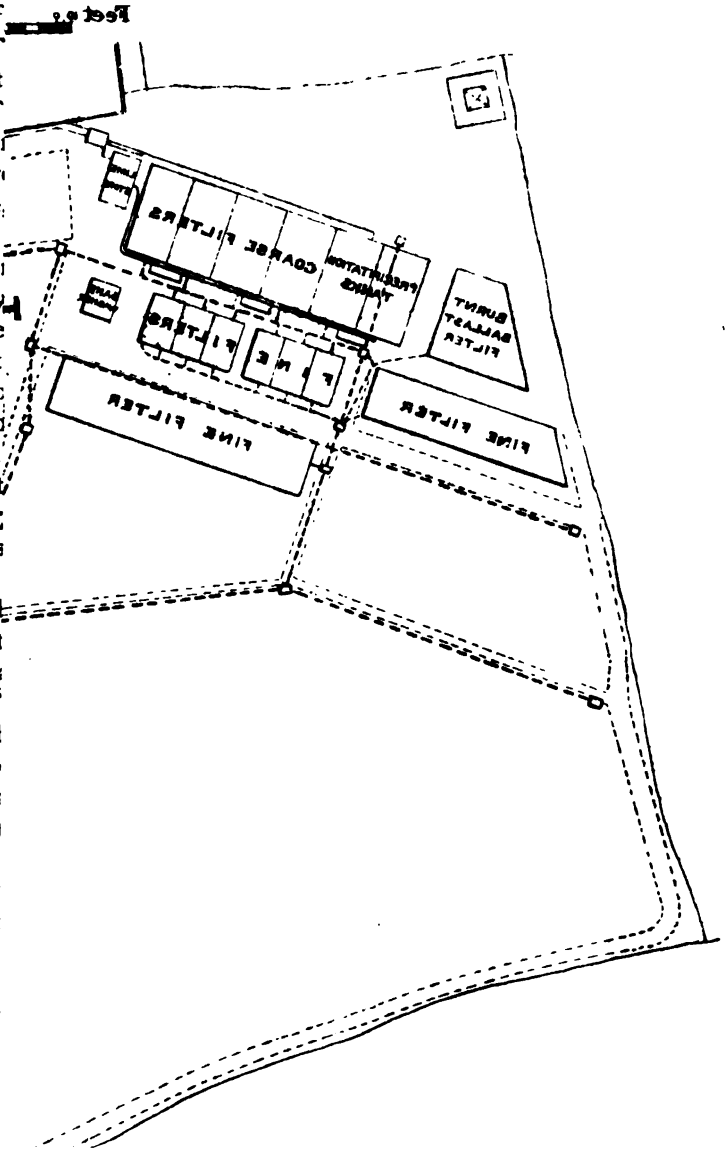

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enters the sewers by direct means, but after rain the percolation of subsoil water increases the daily flow, and at times the total rises to 800,000 gallons. The town is thus drained on the separate system, and the sewage is of a domestic and household character in a strict sense. Three-fourths of the quantity flows to the farm by gravitation and the other fourth is pumped into the gravitation sewer near to the tanks.

The farm was laid out and the sewerage works were constructed in 1893. The total area is 25.17 acres, and the land is wholly situate on clay. The scheme was designed as one of chemical precipitation, with filtration of the tank effluent through artificial filters and the application of the filtrate to land. The levels of the farm are such that 15.65 acres can be irrigated with tank-effluent, and 10.27 acres with the filtrate, if desired.*

Six precipitation tanks were originally constructed, each having a water surface of 55 feet by 30½ feet, and a capacity of 50,000 gallons, or 300,000 gallons all told.

The filters were also six in number, each with a filtering surface of 35 feet by 20 feet and a depth of 2 feet 9 inches. The area of each filter is 77 yards, which gives a total of 462 square yards for the six.

In November, 1896, the use of Tank No. 1 for precipitation was discontinued and its use as a coarse bacteria tank commenced. It was at first filled for a depth of 3 feet 6 inches with burnt clay ballast from which the finer parts which passed a three-quarter-inch screen had been taken out, and the depth was increased to 5 feet. The content of the filtering material in this and the other coarse filters is 8,387 cubic feet or 310 cubic yards.

In March, 1897, Tank No. 2 was filled to a depth of 5 feet with burnt ballast in layers of varying coarseness. The bottom 2 feet passed a screen with a mesh of one-sixteenth of an inch. The succeeding layers increase in coarseness until at the top the pieces of burnt ballast are as large as hens' eggs.

Tank No. 3 was also filled in 1897 in the same manner as No. 1, and in 1898 Tank No. 4 was likewise converted.

Tanks 5 and 6 are used for chemical precipitation, as first designed. Nos. 1, 2, 3 and 4 are thus coarse bacterial filters with a total content of 33,548 cubic feet or 1,240 cubic yards.

The whole of the six original filters have been changed into fine bacteria beds, and two others have been added.

Filter A contains 2 feet 9 inches in depth of burnt clay ballast which has passed a half-inch screen and includes the fine stuff, and thus has a content of 1,925 cube feet or 71 cube yards.

*See Plate IX.

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Filters B, C and D each contain layers of various materials. On the bottom of each there is 5 inches of coarse gravel, then 4 inches of pea gravel, then 5 inches of sand, followed by 13 inches of coke breeze, which was held back by a $\frac{5}{16}$-inch screen, and not exceeding one inch, and on this the top layer, 8 inches thick of coke breeze, which passed a $\frac{5}{16}$-inch screen. Each has a content of 2,052 cube feet or 76 cube yards.

Filters E and F are made on waterworks lines. The bottom 5 inches is of coarse gravel averaging two inches in size, then follows 5 inches of pea gravel, 5 inches of coarse sand and 20 inches of fine sand as the top layer. These have the same content as B.

Filters G and H are not brick structures like the six just described. Advantage was taken of the fact that the sub-soil was stiff clay, and two excavations were made in it, the material obtained was burned into ballast, and after it was screened part was replaced to form the filtering material. The clay sides and bottom are naturally watertight.

Filter G has a filtering surface 131 feet long and 34 feet wide, or 495 square yards. It has 22 inches of burnt clay ballast ranging in size between $\frac{3}{8}$ inch and $\frac{3}{4}$ inch, and on this there is 10 inches of fine coke breeze, making a total depth of 2 feet 8 inches. The content of filtering material is, therefore, 11,878 cube feet, or 440 cube yards.

Filter H is 180 feet long and 36 feet wide, and has a filtering area of 720 square yards. On the bottom there is 23 inches of burnt clay ballast of the same size as in filter G, followed by a similar 10-inch layer of coke breeze, making a total depth of 2 feet 9 inches. The content is 17,820 cube feet or 660 cube yards.

The fine bacterial filters have a content of 41,883 cube feet or 1,551 cube yards.

In addition to the Dibdin filters just named there is a filter with porous walls having an area of 308 yards, containing 8 feet of burnt ballast in various layers. It was intended to be one of Colonel Ducat's filters, but he is not satisfied with its construction and disclaims it as representing his process.

The whole of the sewage passes through a wire mesh rotatory screen, which thoroughly removes the floating solids and paper.

200,000 gallons per day are treated chemically with 9 grains of lime and 2 grains of protosulphate of iron and passed through precipitation tanks 5 and 6, and the tank effluent is passed either on to the land or through the fine bacteria filters.

120,000 gallons per day are dealt with in the four coarse bacteria filters, and then passed to the land or into the fine filters.

80,000 gallons per day are passed through the so-called Ducat filter, and then on to the land or into the fine filters.

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When the infiltration of rain water into the sewers raises the quantity, each of the above proceses receives its proportion, but the excess does not in any case exceed double the dry weather flow.

The working of the Dibdin filters is as simple as can be.

On the top of the filtering material in the coarse filters there is a shallow distributing channel into which the screened crude sewage is turned, and from which it overflows into the burnt ballast. When the liquid rises to within an inch or two of the top, the sewage is diverted into another filter. The charged filter is allowed to stand full for two hours and then the outlet valves are opened and the contents discharged. The air passes freely into the filter as the liquid is discharged and a period of 2 or 3 hours is given for aeration, after which the filter is then ready for use again.

The operation of the fine filter is identical with that of the coarse one.

The liquid which is discharged from the coarse filter is turbid and has a modified sewage odour when shaken up.

The filtrate from the fine beds is slightly opalescent for the first few minutes of the discharge, but it then clears itself and is bright and inodorous.

The filters deal with the whole of the constituents of the sewage without producing sludge or any bye-products, and the following list of average results abstracted from the analyses of Mr. Dibdin show the changes effected:

Results stated in grains per gallon.

For 7 weeks ending 29th March, 1897.

	Crude sewage.	Coarse bed filtrate.	Fine bed filtrate.
Suspended matters	35.40	2.65	0.954
Chlorine	7.45	6.41	6.00
Oxygen absorbed in 4 hours	4.025	1.717	0.608
Nitrogen as Nitrates	0.003	0.424	1.413
Nitrogen as Nitrites	0.030	0.210	0.043
Free Ammonia	6.635	2.180	0.237
Albuminoid Ammonia	0.725	0.298	0.158

For 7 weeks ending 24th May, 1897.

	Crude sewage.	Coarse bed filtrate.	Fine bed filtrate.
Suspended matters	84.66	2.91	0.497
Chlorine	8.51	7.47	7.56
Oxygen absorbed in 4 hours	3.546	1.452	0.620
Nitrogen as Nitrates	0.000	0.399	0.723
Nitrogen as Nitrites	0.001	0.120	0.048
Free Ammonia	4.778	2.027	1.154
Albuminoid Ammonia	0.786	0.360	0.178

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In connection with one of my own schemes I had occasion to secure the services of the eminent chemist, Sir Edward Frankland, F.R.S. etc., and he personally took samples of the crude sewage, and the filtrates in January, 1898.

With the consent of my clients I set out his analyses hereunder:

Results expressed in parts per 100,000.

	Crude sewage.	Coarse bed filtrate.	Fine bed filtrate.
Total solid matters	96.2	84.6	96.1
Suspended matter—			
Mineral	20.0	Turbid	Turbid
Organic	53.8	Turbid	Turbid
Organic Carbon	4.458	1.514	.989
Organic Nitrogen	.898	.308	.173
Ammonia	7.0	2.0	.82
Nitrogen as Nitrates and Nitrites	.0	1.011	2.645
Total Combined Nitrogen	6.663	2.966	3.493
Chlorine	11.6	8.5	11.2

I requested Sir Edward to furnish me with his opinion as to whether the results were within the standards set up by the Royal Commission appointed in 1868 to inquire into the best means of preventing the pollution of rivers, of which he was a member, and he replied: "You will see that the final effluent of the aerobic filter is, in every respect, well within the Rivers Commission standards. The nitrification has been very energetic whilst the raw sewage was above average strength. I collected the samples myself."

As an illustration of the times of working the coarse filters I may say that during August, 1898, Nos. 1 and 2 were in use 27 days and were each charged 81 times; No. 3 was in use 21 days and was charged 63 times, and No. 4 was in use 31 days and was charged 93 times; that is, 3 times per working day.

The three cycles of each coarse filter are as follows:

	H. M.
Filling	0—20.
Standing full	2— 0
Emptying	0—45
Aerating	2— 0
Total	5— 5

or a total of 15 hours 15 minutes—and for the remainder of the day the filter is recuperating.

The cycle of the fine filters is similar to that of the coarse ones.

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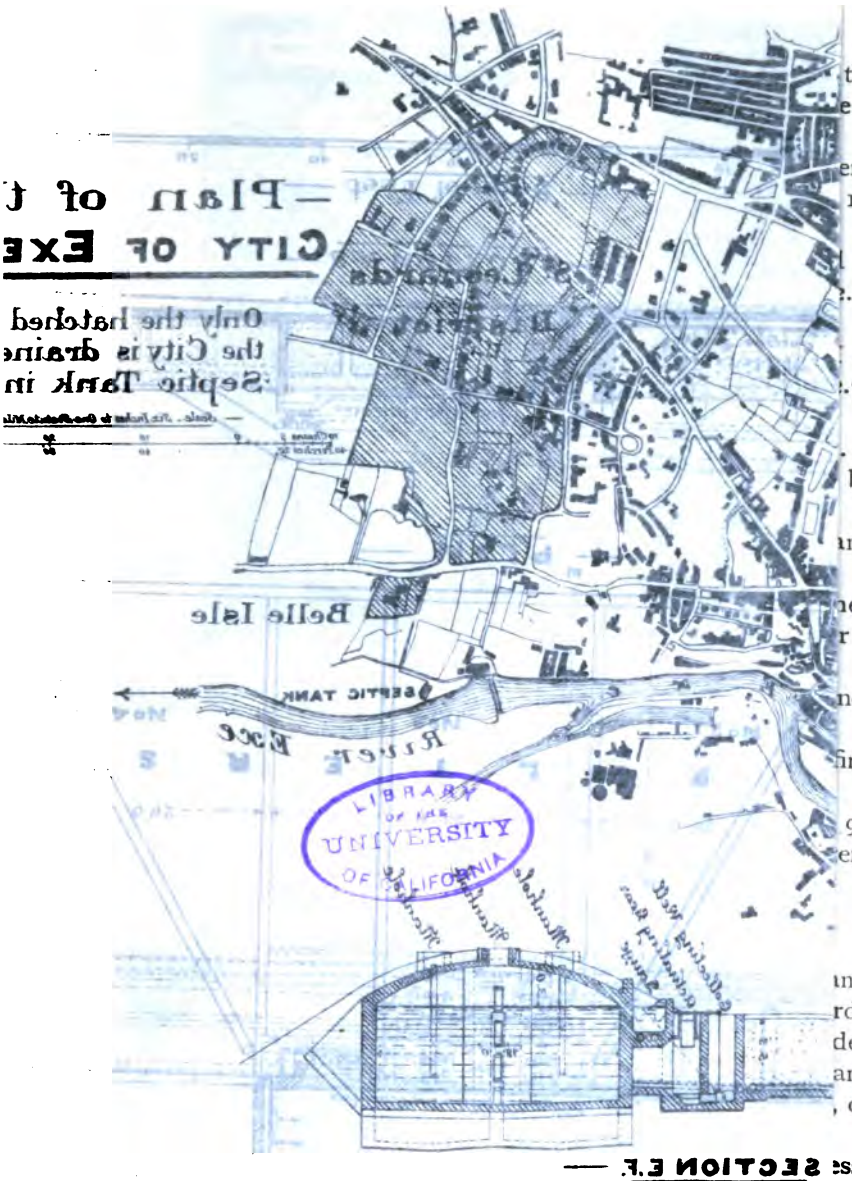
Belle Isle
SEPTIC TANK
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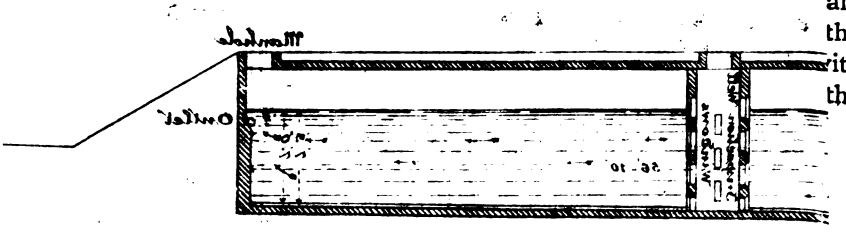
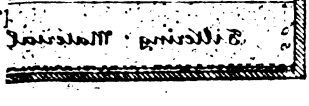
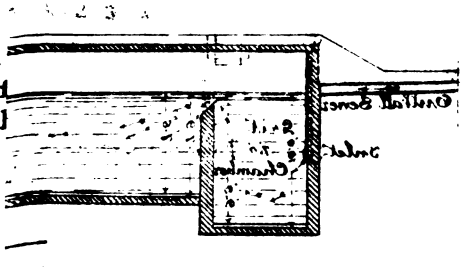

Manhole
Outlet
Inlet





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Coarse filter No. 1 was put into action in November, 1896, and, to the end of November, 1898, has been charged 1,625 times, on an average of 2¼ times per day.

Coarse filter No. 2 was put into action in March, 1897, and, to the end of November, 1898, has been charged 1,156 times, on an average of 1.9 times per day.

Coarse filter No. 3 was started in July, 1897, and, to the end of November, 1898, has been charged 1,097 times, on an average of 2.21 times per day.

Coarse filter No. 4 was started in April, 1898, and, to the end of November, 1898, has been charged 583 times, on an average of 2.71 times per day.

At the outset the water content of the coarse filter was 32 per cent. of the content of the tank to the top of the filtering material, but it has by use deteriorated to 19 per cent.

The water content of the fine filters may be taken at 33 per cent., and does not vary when once the filter is in condition.

There is no accumulation of sludge in any of the filters, and when dug into there is no appearance of any sewage matters, and the odour is only that of damp earth.

The differentiation of the layers and filtering materials does not appear to be an advantage.

The coke breeze appears to be the more suitable material for the fine filters, but it is not much superior to burnt ballast.

The experience at Sutton shows that the coarse filters deal with 95 gallons per cubic yard per day of filtering material, and the fine filters with 208.4 gallons.

Cameron's Septic Tank.

On Drawing No. 2* I have shown a plan of the City of Exeter, and have hatched the district of St. Leonards thereon. The St. Leonards district is within the city boundaries, but it has a set of sewers independent of the sewers which drain the other and more important parts of the city. The total population of Exeter is about 38,000, of which 1,500 reside in St. Leonards.

The experiments on sewage treatment by the septic-tank process, conducted by the city authorities under the direction of Mr. Donald Cameron, the City Surveyor, have been made with the sewage of the St. Leonards district only. In 1896, after a small experiment with part of the sewage, the whole of the dry weather flow and part of the

*Plate X.

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rainfall was dealt with by the installation at present working, and which is shown on the drawing.

The sewage is wholly domestic and in dry weather amounts to 31,380 gallons per day.

The main sewer is 24 inches in diameter, and previous to the septic tank treatment the sewage was discharged from it into the River Exe in a crude state.

In order to divert the sewage to the septic tank, a small sump is sunk in the 24-inch sewer, 8½ inches below the invert, and immediately on the down-stream side a weir 8 inches high is built across the sewer.

From the bottom of the sump a 6-inch drain is laid on the right hand of the sewer looking down-stream, discharging into a covered manhole adjoining the main sewer, in which there is a detritus chamber 4 feet square and 18 inches deep below the invert of the drain, for the collection of grit and mineral substances. This manhole is connected to the septic tank by a 6-inch drain 155 yards long, with a gradient of 1 in 1,000 and a maximum discharge by careful gauging of 122,040 gallons per day.

The works described completely divert the whole of the dry weather flow of sewage without any screening to the septic tank, and also the rainfall up to three additional volumes, any excess of rain overleaps the weir in the sewer and flows direct into the river.

Close to the septic tank there is a small shallow distributing chamber from which two separate 6-inch drains convey the sewage to the tank itself.

The septic tank is a covered rectangular structure, with a slightly sloping bottom, vertical walls and segmental roof. Its internal length is 64 feet 10 inches, its breadth is 18 feet, and the mean depth of sewage when working normally is 7 feet 4½ inches. The bottom slopes 3 inches transversely from the walls to the centre, and 6 inches longitudinally from the outlet to the inlet end. At the inlet end the depth is 7 feet 6 inches at the side walls and 7 feet 9 inches in the centre, and at the outlet end 7 feet at the side walls and 7 feet 3 inches at the centre. The normal level of the sewage is at the springing of the arch, which has a versed sine of 3 feet.

At the inlet end of the tank there is a transverse division wall 7 feet from the end, the top of which is twelve inches below water-level. The space so formed is divided into two equal parts by a division wall on the longitudinal axis of the tank, the top being 6 inches below water-

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level. These two enclosures are known as the grit chambers and have a depth of 10 feet.

In the centre of the tank there is a covered inspection well. The bottom of the well is level with the bottom of the tank, and its mouth is at the top of the roof. In its sides are stout glass windows, and its only purpose is to afford facilities for inspecting the action of the process on the sewage.

There are also three manholes in the roof for access to the tank itself and also six small 3-inch holes for sampling. The manholes and sampling places are covered.

Although the tank is not, strictly speaking, gas-tight, yet there is no free communication from the inside with the air and light.

The two 6-inch drains which come from the shallow manhole go into the grit chambers, one to each. Their inverts are at normal water-level, but both pipes are continued downwards for five feet, so that the incoming sewage is discharged that depth below the surface.

At the outlet end of the tank the discharge pipe is fixed on a ledge on the wall 16½ inches below the water. The pipe is slotted and extends the whole width of the tank. The outlet is, of course, turned up 16½ inches, and at the beginning it discharged direct into the aerating chamber. A small sedimentation chamber was added to the tank in July, 1898, for the purpose of arresting the matters which appeared on the surface of the filters as scum, and into this chamber the sewage from the septic tank now flows before it goes to the aerator.

The water content of the septic tank is 53,800 gallons.

The aerator chamber contains a V notch for gauging the flow of sewage, and after passing it the sewage flows into a shallow trough 7 feet long and falls over the sides into the pipes which distribute it onto the filters.

There is no screen for arresting the solids on any part of the works.

There are five filters having an area of 80 square yards each. The walls are vertical and the bottom flat, with a fall of 3 inches toward the outlet end. In each there is an average depth of 5 feet of filtering material.

On the bottom of the filters there are 3-inch collecting drains, laid parallel to each other, and over and between them there is a layer of coarse gravel following the slope of the floor 6 inches thick. In all other cases the filtering layers are level on their top surfaces.

No. 1 filter is filled above the gravel with broken clinker which passed a half-inch screen and was held by an eighth-inch screen, but the top 3 inches is of finer stuff.

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No. 2 filter is the same as No. 1, save that the first 10 inches of clinker above the gravel is coarser than the rest, having passed an inch screen and being held by an eighth-inch screen.

No. 3 filter has above the gravel 10 inches of coke breeze which passed an inch screen, and then 44 inches, that is, to the top, with coke breeze which has passed a half-inch screen.

No. 4 filter has above the gravel a 10-inch layer of clinker which passed a one-inch screen and was held by an eighth-inch screen, then 32 inches of clinker which passed a half-inch screen and was held by an eighth-inch screen, and then 12 inches of coke breeze which passed a half-inch screen.

No. 5 filter has above the gravel 42 inches of clinker which passed a half-inch screen and was held by an eighth-inch screen, and then 12 inches of coke breeze which has passed a half-inch screen.

A semi-circular distributing pipe is embedded on the filtering material in each filter, with its top level with the surface. In filters 1, 2, 4 and 5 this pipe is laid diagonally, but in filter 3 it is parallel to the long sides.

The effluent drain from the outlet wells is level with the bottom of the filters and discharges direct into the river.

There is an ingenious automatic alternating gear which is operated by an overflow from the filters. When a filter is fully charged, some of the filtrate overflows and fills a tilting basin, which closes the outlet valve of the filter which is next to be filled, opens the inlet valve of the same filter, shuts the inlet valve of the filter which has just been charged, and opens the outlet valve of the filter which is to be discharged.

The working of the process is simple and automatic.

The sewage from the main sewer passes into the grit chambers and then into the septic tank, and overflows therefrom into the shallow trough. In dry weather the sewage was in the tank about 40 hours when it was first put to use. A deposit on the bottom of the tank has taken place at the rate of 1¼ inches per month, and after 26 months' continuous work there is a total depth of 35 inches. On the surface of the sewage there is a layer of scum 2 inches thick which gathered in two months after the start, which increases in winter and decreases in summer. The space between the top of the deposit and the under side of the scum layer is that through which the sewage passes.

There is a constant rising of gas bubbles from the bottom to the surface, carrying with them small particles of solids, which fall off as the bubbles rise.

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The gases generated rise into the space between the scum and the roof, and escape through the concrete when they are not used for lighting, or are liberated by the removal of the covers for inspection. There is no pressure in the tank at any time, even when no means are taken to draw off the gases.

The tank effluent in the shallow trough is apparently putrefying, and a slight smell is to be observed there.

The filters are used in combinations of four. The tank effluent is turned into each in rotation and fills the interstices to the top of the filtering material, and is then automatically diverted into another filter. The filter which is filled is allowed to rest full until the automatic gear is next operated by the filling of the next filter, when the outlet valve is opened and the liquid is discharged into the river. The filter is then allowed to rest for a time, which is determined by the rate of flow of the sewage, and is then filled again and the cycle is repeated.

The working of the filters is such that every fifteen or sixteen days one of the five has two or three days' complete rest.

When the filtering material was first put in, the water space was 38 per cent. of the bulk occupied, but during use this diminishes to 26 per cent. After the two or three days' rest, however, it recovers itself, but not quite to 38 per cent. A fair mean of the whole time of use would be 33⅓ per cent.

A scum gradually accumulates on the surface of the filters, and is removed once or twice a year by taking out the filtering material to a depth of 2 inches.

The present installation commenced work on the 21st August, 1896, and has gone on uninterruptedly until to-day.

The detritus manhole near the outfall sewer has been emptied from time to time, and about one cubic yard of mineral matter taken out. When this is done the deposit is stirred up so as to send all the organic matter to the tank.

The two grit chambers in the tank have not been emptied.

Except the mineral matter, the installation has dealt with the whole of the sewage of the St. Leonards district and a proportion of the rainfall up to a total of 122,000 gallons per day, and disposed of it, except the deposit and scum in the tank.

The first rush of the filtrate is opalescent, but it soon becomes clear and bright, and is without smell.

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The analytical results of the process are as follows:
By Dibdin and Thudichum. (April and June, 1897.)

Results in grains per gallon.

	Crude sewage.	Tank effluent.	Filtrate.
Suspended Solids.			
Mineral	10.0	3.5	Practically
Organic	14.5	7.8	nil.
Dissolved Solids.			
Mineral	14.0	16.1	20.3
Organic	15.9	14.6	24.2
Chlorine	5.0	5.1	5.3
Oxygen absorbed in 4 hours	2.028	1.405	0.388
Nitrogen as Nitrites	.....	.....	0.253
Nitrogen as Nitrates	.....	.....	0.353
Free Ammonia	3.778	2.763	1.705
Albuminoid Ammonia	0.212	0.175	0.078

Another series of analyses by Messrs. Pearmain and Moor are set out hereunder:

Results in grains per gallon.

Averages of six samples of each.

	Crude sewage.	Tank effluent.	Filtrate.
Total Solids	57.1	37.67	31.5
Mineral Matter	28.3	24.5	24.83
Loss on Ignition	28.83	13.17	6.67
Chlorine	6.05	4.51	4.51
Oxygen Absorbed	4.21	1.41	0.32
Nitrogen as Nitrites	.....	.....	.....
Nitrogen as Nitrates	.....	.....	0.91
Saline Ammonia	4.36	2.83	1.19
Albuminoid Ammonia	0.74	0.40	0.11

Yeovil Septic Tank.

Visit 8th November, 1898.

The sewer from which the sewage passed through the septic tank is obtained, conveys one-sixth of the whole of the sewage of the borough, and of this one-sixth about one-quarter only is intercepted; that is to say, the quantity treated is actually one-twenty-fifth of the town's sewage. The sewer selected conveys an average quality of the town's sewage, and was chosen for that reason.

There is a large admixture of liquid trade refuse with the sewage, consisting in the sewer tapped of brewery refuse, the waste from leather-staining and dyeing, etc. The chemicals used by the traders include large quantities of red arsenic, sulphates of copper, iron and zinc, alum, salt, potash, lime, hydroleine and vegetable colouring.

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The sewer containing the one-sixth of the sewage is 21 inches in diameter, and is tapped at a manhole by a 6-inch pipe, having its invert level with that of the 21-inch pipe. The centre line of the 21-inch sewer is straight in plan, but on the left-hand side of it, looking in the direction in which the sewage is flowing, the 6-inch drain branches off, having its mouth in the same face of the manhole as the down-stream part of the 21-inch sewer. The mouths of the sewers are within six inches of each other. In order that there may be diverted into the 6-inch drain a proper proportion of the floating solids, a board two inches deep is placed in the manhole at an acute angle across the 21-inch sewer, with its top level with the soffit of the 6-inch sewer. The upstream end of this board is against the right hand side of the channel in the manhole, and its down-stream end is fixed against the manhole wall between the two sewers. There is thus a space below the bottom of the board, varying from nothing at the ends to four inches in the centre, through which the sewage flows to the 21-inch sewer in an unobstructed manner. When the depth of sewage flowing in the 21-inch sewer is above the bottom and below the top of this board, the whole of the solids floating on the surface are diverted into the 6-inch drain. At other times there is a rough division of the quantity between the sewers, but the proportions cannot be stated with accuracy.

There is a manhole on the 6-inch drain about 15 feet from the septic tank, in which the grit partly subsides. This is cleaned out from time to time by hand, care being taken to vigorously stir the deposit so as to free it from organic matters. The deposit removed is lying alongside the manhole and is mineral matter. In this manhole there is an overflow pipe discharging into the continuation of the 21-inch sewer.

The effect of the intercepting arrangements described is that the flow of sewage into the tank is at a fairly even rate all the day. When rain occurs, the greater part of the increased quantity in the main sewer flows over the board into the 21-inch sewer at the first manhole, and what little of it is forced through the 6-inch drain by the increased head in the manhole is spilled by the overflow in the second manhole.

The septic tank is roofed over with a brick arch, and has a flat bottom, vertical walls, and is more or less air-tight.

It has an internal length of 50 feet, a breadth of 12 feet and a depth of sewage of 6 feet. At the inlet there is a transverse cross wall 5 feet 6 inches from the end, and the space so formed is divided into two by a central wall; and both of these walls have their tops about 2 inches below water-level. The two spaces so formed are called grit chambers.

Each of these grit chambers receives one of the two 6-inch sewers which leave the second manhole, and the inlet pipe is continued down-

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wards to within 2½ feet of the bottom. The level of the sewage in the tank is the same as the inverts of the 6-inch sewers, where they enter the tank wall just where the descending pipes commence. The septic tank, including the grit chambers, holds 22,000 gallons of sewage when working normally.

The outlet from the tank consists of a 5-inch slotted pipe laid on a bench on the end wall furthest from the inlet, about 16 inches below the sewage level, and discharges into a small measuring well or manhole outside the tank.

The filters are now six in number and have a surface area of 240 square feet each, and a depth of 3 feet, which equals a total of 160 square yards in area and of 160 cubic yards in content.

There is an automatic gear for opening and shutting the valves which admit the tank effluent to the filters, and the filter effluent into the Dodham Brook, adjoining the works. These valves are actuated by the overflow of the tank effluent from the filter which is being filled passing into a bucket-tilting arrangement, which diverts the tank effluent to an empty filter, and liberates the water in the filter which has been standing charged. Two of the filters are out of use for aeration and recuperation in regular rotation for three days, at intervals of six days; that is to say, four filters are actually doing the work at any given time.

When the works were first started in September, 1896, the 6-inch sewer delivered 22,000 gallons per day to the tank. The filters were then three in number, each of which was subsequently divided into two, making the present six, so that the total area and content at the outset were slightly in excess of the present ones by the area and cubic content of the new division walls.

The material in the first filters was coke of a rather coarser nature than is now used for filtration, varying in size from 1¾ inches to buckshot pieces.

The original arrangement was in use from September, 1896, to February, 1898, or 17 months.

It was found in practice that with three filters, one of which was recuperating, it was necessary to discharge the others without any period of standing full, and this, together with the coarseness of the filtering material, told against the quality of the filtrate.

Accordingly, in February, 1898, the works were thrown out of use and the filtering material removed. There was no accumulation of sludge or deposit on the bottom of the filters or on the filtering material.

The filters were each divided into two by a central longitudinal

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division wall, and refilled with carefully selected fine filtering material, as under—

No. 1 Filter—Broken clinker with a layer of chalk.
" 2 " —Broken coke.
" 3 " —Broken coke.
" 4 " —Locomotive smoke-box cinder.
" 5 " —Broken clinker.
" 6 " —Broken clinker.

The depth of 3 feet was not altered. Across each filter in a diagonal direction there is a semi-circular distributing pipe bedded to the lip in the filtering material.

On May 21st last the new filters were put into use. All the other works, such as the tank, the 6-inch sewers, etc., were not altered in any way.

By the new arrangement each filter has a quiescent time of one hour, at least, when full, and this, together with the finer materials, has resulted in an improved effluent.

The grit chambers have been cleared of mineral matters four times since September, 1896, but the total amount of deposit in the septic tank is only one inch from the commencement to date.

The stream into which the effluent is discharged shows no fungus at the outlet.

The experience of the Council has determined them to apply this system to the whole of the sewage of the town, and a scheme for doing this is in operation.

The ratio of one day's flow as the capacity of the septic tank, will be followed in the new scheme, but the ratio of filtering capacity in relation to the dry-weather flow will be somewhat increased.

Lowcock's Aerated Bacterial Filters.

The original experiments by Mr. Lowcock of forcing air into an artificial filter to assist in the treatment of sewage were made at Malvern Link in 1892, but his later and more matured trials have been made at Wolverhampton and Tipton.

The Malvern Link Experiments tended to show that a quarter of a million gallons of crude sewage could be dealt with on a filter having an area of one acre, but that there was considerable difficulty from the clogging of the surface. The experiments with tank effluent after the crude sewage has been chemically treated were freer from difficulty, however, and the installations at Wolverhampton and Tipton deal with tank effluent only.

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In 1894 a sand and gravel filter was made on Mr. Lowcock's system at the Wolverhampton Sewage Works with an area of 12 square yards and of the following section. The bottom layer is 6 inches deep and consists of one-inch pebbles, and in it are the underdrains. On it 6 inches of ½-inch gravel is laid, followed by 3 feet 9 inches of gravel and dolomite chippings averaging ¼ inch in size. On the top of the chippings the perforated air pipes are laid, and they are surrounded and covered by 6 inches of one-inch pebbles. There then follow three layers of gravel and sand each three inches deep, thus making a total depth of filtering material of 6 feet. It will be seen that the air pipes are 15 inches below the surface.

The air was driven into the filter at a pressure of 3 inches of water by a Root's blower.

After the crude sewage had been treated with lime the tank effluent was applied to the filter at the rate of 1,000,000 gallons per acre. For the first month nitrification proceeded slowly, but the efficiency of the filter gradually increased until after one year's working the following results were obtained:

Results stated in parts per 100,000.

	Tank effluent.	Filtrate.
Chlorine (grains per gallon).....	14.0	16.8
Oxygen absorbed.....	1.7	0.4
Nitrates.....	Traces	2.68
Free Ammonia.....	4.0	1.20
Albuminoid Ammonia.....	0.35	0.07

The tank effluent had been applied continuously to the filter in an even stream, except that once a week the surface was allowed to dry and it was then raked over, and at intervals of 8 weeks the top ⅛ inch of sand was removed to get rid of a fungus growth, which gradually developed and clogged the filter.

At the end of twelve months the experiment with this particular filter was abandoned and it was then found that the top inch of sand was discolored and dirty, but otherwise the filtering material was sweet.

The whole of the sand and gravel was removed and the following arrangement of coke filtering was placed in its stead.

The bottom layer is six inches deep and consists of broken coke about one inch in size, and in it are the under-drains. On this there is 6 inches of finer coke and then 3 feet 9 inches of fine coke breeze of, say, ⅛-inch pieces. The perforated air pipes lie on the surface of the 3 feet 9 inches bed and are covered with 6 inches of one-inch coke, followed by two three-inch layers of coke and a top layer of sand three inches deep.

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The coke filter is thus a repetition of the sand and gravel filter as regards the depths and sizes, save that in both the top 3 inches is of sand.

Two years' working of this filter gave pratically the same output and results as the sand and gravel filter.

In 1896 Mr. Lowcock constructed two filters at Tipton,* where the sewage is first treated with lime and alum. The area of each is 16 square yards and the total depth of filtering material is 3 feet 6 inches. The bottom 6 inches consists of one-inch pebbles and contains the underdrains, and on it there is 6 inches of coke breeze of half-inch pieces. Then comes 15 inches of fine coke breeze and limestone of one-quarter-inch pieces, and on this the perforated air pipes are placed. Above the pipe there is a 6 inch layer of one-inch pieces of coke, then 6 inches of fine coke breeze and limestone, and the top 3 inches is fine sand.

The perforated pipes are 15 inches below the surface, as in the other filters.

When the filters were first put into use, tank effluent was applied at the rate of 120 gallons per square yard per day (580,800 gallons per acre), and the quantity was gradually increased to double. The air is supplied to the filter at a pressure of one inch of water.

While the filters were used for 24 hours each day, some trouble was experienced from the clogging of the surface and a change was made by using them for 12 hours only, and applying as much tank effluent in that time as was previously put into the filters in 24 hours when they were worked continuously. That is to say, in 12 hours the tank effluent was applied at the rate of 2,323,200 gallons per acre, and allowing for the 12 hours rest, the output for 24 hours was 1,161,600 gallons per acre.

The analytical results are shewn hereunder, the figures given being the averages of 8 samples taken from January to September, 1897, and analyzed by Dr. Reid, the Medical Officer of Health for Staffordshire.

Results in grains per gallon.

	Tank effluent.	Filtrate.
Solids in Solution	79.62	80.75
Solids in Suspension	1.75	1.37
Chlorine	10.25	10.07
Oxygen absorbed in 4 hours	0.708	0.223
Nitric Nitrogen	Nil.	0.74
Free Ammonia	1.075	0.277
Organic Ammonia	0.231	0.056

Mr. Lowcock's experience is that there is little to choose between coke, coal, gravel or broken stone as the filtering material, but he attaches importance to its being sufficiently fine and properly arranged.

* See Plate XI.

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The Ferozone-Polarite Process.

By common consent the sewage disposal works at Chorley, Lancashire, are the best example of the International Company's Ferozone and Polarite process at the present time.*

The population of the borough is 25,000, of whom 22,000 contribute to the sewage works, which are about one mile from the town and are situated on 6 acres of land, which were formerly used as part of the sewage farm. In the town there are about 1,800 water-closets and 2,500 tubs or pails. The latter when filled with excreta are conveyed in covered vans to a central depot, where the pail stuff is given away to farmers when they will take it, but in harvest times, when the hay crop is being gathered, and during wet weather they do not come for it, and it is then turned into the sewers at the depot in the town after admixture with a small quantity of disinfectant.

The town is supplied with water from the Liverpool works, and I am informed that the daily user per head averages 17 gallons. Very little manufacturing refuse is turned into the sewers; the principal being from a small tannery.

The road and roof and yard drains are connected to the sewers, and a small brook called the River Chor discharges into them, but its contribution does not exceed 125,000 gallons per day.

The outfall sewer from the town is tapped near the works by a branch pipe leading to the precipitation tanks, and the dry water flow of 800,000 to 960,000 gallons per day is regularly and systematically dealt with. About 6,000,000 gallons per day, all told, come to the works during wet weather, which is chemically treated in the tanks, but is not all passed through the filters.

There are eight precipitation tanks 90 feet x 47 feet 6 inches x 6 feet, holding 160,000 gallons each, or 1,280,000 gallons all told. This is about one and a half days' dry weather flow.

The chemicals used were formerly Ferozone and now Ferral in the proportion of about 10½ grains per gallon, including the storm waters.

The sewage after admixture with the chemicals is allowed to stand in the tanks at rest from 2 to 2½ hours.

The sludge is pressed, 45 tons of cake per week being turned out and sold to farmers.

There are 15 polarite filters, each 55 feet 6 inches x 15 feet=92 square yards, or 1,380 square yards in all.

The tank effluent flows into a covered distributing channel, rectangular in section, which extends the whole length of the filters.

* See Plate XI.

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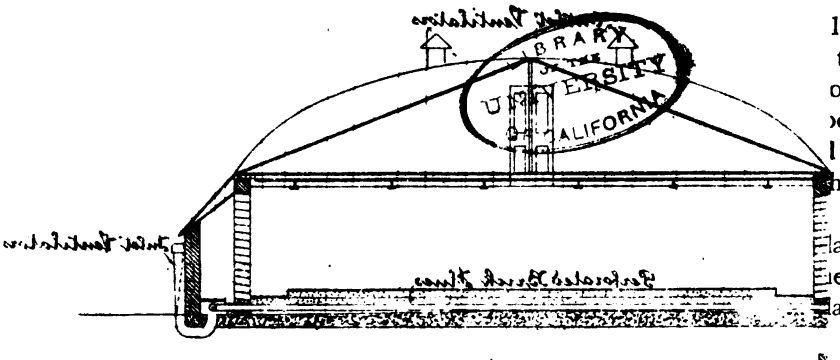

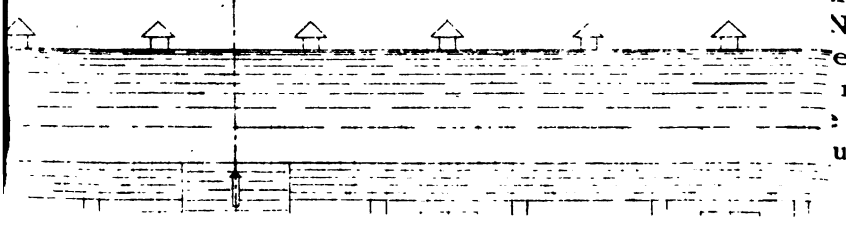

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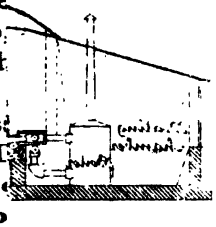

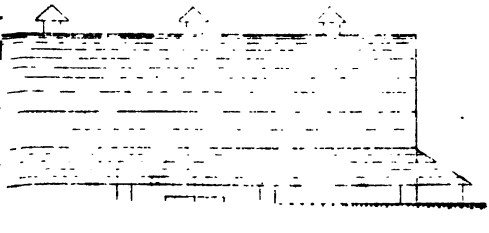

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From this channel 15 branch pipes conduct the tank effluent to the 15 filters, and the discharge is regulated by an upward moving sluice door actuated by hand.

At each end of the channel there is a square-headed weir penstock working downwards, by means of which the whole or part of the tank effluent may be sent to the river without going through the filters. When these penstocks are in their normal position (that is to say, closed,) the tank effluent in the channel cannot overflow them without first escaping on to the roadway in front of the filters, and thus revealing the fact that the tank effluent is not passing through the filters.

The inlets to the filters are at one of the narrow ends, and a shallow rectangular iron channel, 12 inches by 3 inches, runs longitudinally along the centre of each at the level of the top of the sand, and into this the tank effluent is discharged when the inlet sluice door is opened, and is distributed over the surface of the filter.

At the outlet end of this channel there is another sluice door which is kept shut when the filters are at work, but which is opened when the surface of the sand is being washed.

The filtering material consists of 18 inches of clean washed gravel at the bottom, ranging from an inch-and-a-half to one-eighth inch in the longest dimensions, laid in layers with the largest stones at the bottom, and gradually decreasing in size until the top layer, which is fine pea-gravel. Then follows twelve inches of polarite and sand mixed in equal proportions, and on this there is nine inches of ordinary washed filter sand. The total depth is thus 3 feet 3 inches.

There are eight 3-inch perforated horse-shoe tile under-drains laid longitudinally on the bottom of the filter in the gravel. Two of them are against the division walls at each side, and the other six are laid equidistant from each other and parallel to the division walls.

Against the outlet end wall and on the bottom of the filter floor there is a 6-inch drain into which the longitudinal under-drains discharge, which passes through three filters and discharges the filtrate from the three filters into the outlet pipe, which is controlled by a valve.

This triplicate arrangement assists in the washing of the sand surface. When this operation is being performed the three inlet doors are closed and the filtrate is allowed to flow out until the sand surface appears. The outlet valve is then shut and the liquid in the three filters is thus imprisoned. If the surface of No. 1 is to be washed, the inlet doors of No. 2 and No. 3 are opened, and tank effluent is allowed to flow in until there is a head of 4 inches on them. This goes down as usual, but having no outlet it backs up the under drains into No. 1 and rises to the surface of the sand therein. The outlet valve on the shallow channel on the sur-

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face of No. 1 is opened, and the surface of the sand is brushed to remove the dirt, and the dirty water escapes by means of the shallow channel to the wash water tank below the filters. The head of tank effluent is kept up in Nos. 2 and 3 until No. 1 is cleaned, then the inlet valves are closed, the top outlet on No. 1 is shut and the bottom outlet valve of the triplicate tanks is opened and the filtrate escapes until the sand is exposed on all the three filters. The bottom outlet valve is again closed, tank effluent is turned on to Nos. 1 and 3, the top outlet door of No 2 is opened, the sand surface of No. 2 is washed, and so on.

In addition to the brushing of the surface by soft brooms a rake is also used, which goes three inches into the sand. By this means the dirt below the surface is washed out. The brushing and raking is done weekly.

It is also found necessary every 4 or 6 weeks to dig and turn over the sand as deep as the polarite layer to clean it thoroughly, and this is done when the filter is resting.

The outlet valve of the filters is always open except when the filters are thrown out of use for washing. When filtering is going on the inlet doors are opened until the tank effluent stands 3 inches above the sand, when they are closed, and the water sinks to or below the sand surface. Tank effluent is again turned in until it stands 3 inches above the sand as before, and the inlet is again closed until it passes down, and so on, time after time. In practice the fillings occur at intervals of half an hour, but 20 minutes suffices.

Filtering goes on from 6 A.M. to 9 P.M. daily. After 9 P.M. the filters drain themselves empty and stand full of air till 6 A.M.

Four sets of three are in daily use at least. The fifth set of three is either being washed or is resting.

One set of three is thrown out of use and washed in daily rotation, and thus in five days the rotation of the five sets is complete. The washing takes the whole time of two men. On the remaining two days of the week the fifth set of filters is either resting or in use, according to the pressure of work.

The sand washing water flows into a wash tank, and is pumped back into precipitation tank No. 4. The total volume pumped back equals 60,000 gallons per day, for five days per week. The water pressed out of the wet sludge flows back into No. 4.

Crude sewage mixed with an extra quantity of precipitant is turned into No. 4 tank, and mixed with the sand washing water and press liquor, and so far as the eye can see, the effluent from it is as good as any which comes from the tanks,

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Very great care is exercised to get a good tank effluent, particularly in regard to the absence of suspended matters. This is essential to the free working of the filters, for if the tank effluent is cloudy the filters tend to choke.

The intermittent working of the filters is necessary to successful work, as is also the regular washing and digging of the surface of the sand. If the sand is not kept clean the rate of filtration falls off very rapidly.

The filtrate is bright and sparkling, and all along the channel into which it is discharged there is a dark green vegetable growth, which betokens a fully oxygenated effluent.

I had special analyses of the crude sewage, tank effluent and filtrate made for this report by Mr. Frank Scudder, F.I.C., F.C.S., acting for Sir Henry Roscoe, with the following results:

SAMPLES COLLECTED 12TH DECEMBER, 1898.

Chemical results expressed in grains per gallon.

	Crude sewage. 9.00 a. m. to 12.35 p. m.	Tank effluent. 3.00 p. m. to 5.30 p. m.	Filtrate. 3.20 p. m. to 5.30 p. m.
Solids in Suspension.			
Mineral	27.5	....	....
Volatile	59.0	....	....
Solids in Solution.			
Mineral	43.5	52.0	44.0
Volatile	17 5	10.5	11.0
Chlorine	6.8	6.7	4.7
Oxygen Absorbed.			
3 minutes test	2.36	0.69	0.10
4 hours test	7.89	2.31	0.17
Nitrogen as Nitrites and Nitrates.	....	0.005	0.148
Free and Saline Ammonia.	4.02	2.94	0.07
Albuminoid Ammonia	1.162	0.512	0.032
Transparency (millimetres seen through)	20	140	over 530

Mr. Scudder calls attention to the large decrease of the chlorine in the filtrate as an abnormal circumstance.

At *Huddersfield*, where the sewage is mixed with a large quantity of trade refuse, the polarite filters have not answered, and the filtering material is being replaced by coke breeze. There seems to be no doubt that only a part of the total volume of sewage was ever dealt with by

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the filters, and the corporation found themselves unable to filter one-tenth of the daily dry-weather flow.

At *Hendon*, a suburb of London, where the sewage is principally of a domestic character, the Council have not been able to do the quantity of work with the polarite filters which they were designed to do.

At *Lincoln* the polarite filters have not answered the expectations under which they were made. Instead of filtering 1,000 gallons per square yard per day, the City Surveyor informs me that he can only get 150 gallons, notwithstanding that he employs 4 men to wash the sand and keep it clean.

For many years *Hyde*, near Lancashire, was a show place for the polarite system, but the effluents have lately been condemned by the Mersey and Irwell Rivers Board.

Ducat's Aerating Bacterial Self-Acting Filter.

The sewage of Hendon is mainly domestic, and is of a foul character, owing to the large number of laundries for London in the district.

The original Ducat filter was made in January, 1897, and was at work in March of the same year.

The new filter was built in the early months of 1898, and started work in April last.

The root idea of the system is to have an intermittent stream of sewage passing through a fully aerated mass of finely broken material which harbours microbes capable of breaking down the organic matters and converting them into harmless forms.

Neither of the Hendon filters combines all the developments of the standard filter, but the various parts are successfully at work in one or the other.

Before describing the Hendon plant, it will make things clearer if the perfected filter is first dealt with.

Colonel Ducat proposes to use standard units with a filtering area of 126 feet x 36 feet, or 504 square yards, capable of dealing with a dry weather flow of 100,000 gallons per day. If the dry weather flow be 1,000,000 gallons per day, 10 of these filters would be used, and as each is complete in itself the larger flow would be dealt with by the multiplication of the individual units. There is only one very slight qualification of this, viz: that the warming apparatus can conveniently serve two filters, and would, therefore, in practice be placed between each pair, but each unit can have a separate warming apparatus, and be completely independent, if that is deemed best.

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The floor of the filter is made of concrete or other impervious material, and has a slope of 3 inches from the centre towards the long sides and a hip slope of 3 inches towards the ends.

On the bottom there are 28 transverse perforated brick air flues 4 feet 6 inches from centre to centre, measuring about 9 inches x 9 inches in cross section in which the hot water pipes are laid.

The sides of the filter are made as open as is possible, and may conveniently consist of panels of open drain-pipes between brick piers, or vertical iron standards. These panels are 8 feet wide and extend from the floor to the top of the filtering material. On the bottom there are two rows of bricks, with every alternate brick omitted, and the remainder of the panel is made of butt-ended drain-pipes 12 inches long and 4 inches in diameter, laid one on the other as close as possible, and held in place by the cement mortar which fills the spaces outside the pipes. They have a slope of 1 inch upwards from the inside. The panel is thus a perforated wall in which the holes are very much in excess of the solid parts. It has little strength for resisting pressure, but the load is really carried by the standards, or by the heavy brick piers.

The filter has 14 of these panels on each of the long sides and 4 on each of the short ones.

The space so enclosed is filled in the following manner: There are first laid on the floor transverse lines of 3-inch butt-jointed drain-pipes from every space left alternately in the bottom rows of bricks. They are not closely joined at the ends, and thus space is given by which air can escape into the filtering medium.

The space between them is carefully packed with clean furnace clinker of the size of walnuts which has been held back by an inch screen, and the layer is continued above them until its total depth is 6 inches. On this an 18-inch layer of clean furnace clinker is laid, which has passed a quarter-inch screen and been held by an eighth of an inch screen. These two layers have a total depth of 2 feet and form the bottom section of the filter.

On the top of this section transverse lines of 3-inch drain-pipes are laid from the pipes in the panels to the interior in exactly the same way as on the floor, and a 6-inch layer of coarse clinker and an 18-inch layer of fine clinker is put on exactly as in the bottom section, thus completing the second section.

The third section has the aerating pipes and the 6-inch layer of coarse clinker as in the second, but upon the 6-inch layer there is 12 inches of ⅛-inch to ¼-inch vitrified clinker, and then a 6-inch layer of ¼-inch to ½-inch of vitrified clinker, the three layers forming a third section 2 feet deep.

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On it there are laid aerating pipes and a 6-inch layer of coarse clinker as before, and then an 18-inch layer of ¼-inch to ½-inch vitrified clinker, the two layers forming a fourth section 2 feet deep.

In the normal filter there are these four sections with a total depth of 8 feet, but five sections or six sections, or any number, may be used if a very high degree of purification is to be attained, and the extra ones are put in the same as No. 2 and between No. 2 and No. 3.

The filter is by this construction porous from top to bottom, and air is admitted to the filtering material all the way round by the panels, and is carried right into the interior by the transverse lines of pipes in the coarse or aerating layers.

The carrier for distributing the crude sewage is built on one of the long walls, and from it at 18-inch centres there are small outlet pipes discharging into the tipping channels, which are made of iron, light in section, and are fixed transversely about 6 inches above the filtering material. Each channel is 36 feet long and has one vertical side 2 inches high, a short flat bottom one inch wide and a sloping side rising to the same height as the vertical side. They are carefully pivoted at intervals and balanced, so that when they are empty the top is horizontal, but when the sewage rises in them the centre of gravity is shifted towards the sloping side, and the channel tips over and distributes its contents on to the topmost layer of the filtering material. There are 84 of these channels to each standard filter, and as they hold about 4½ gallons of sewage each, it follows that each one must tip every 5 to 5½ minutes on the average when the filter is dealing with 100,000 gallons per day.

On the outside of the panel walls on the four sides of the filter there is an open drain below the level of the floor into which the filtrate escapes at every opening, and by which it is conveyed to the outfall stream or river.

The filter is covered by a roof which rises at the centre 7 feet 6 inches above the walls, and it is enclosed by a brick wall all round, about 18 inches from the panelled walls, and the space between them is roofed in by a small lean-to roof. Thus the filter itself is enclosed and covered in all round.

There are seven doors in each of the long outer walls and two in each of the end ones, for access to this narrow passage, and to admit air to the filter in summer time when artificial heating is not necessary.

There are 28 vertical inlet air-pipes on each of the long outer walls, by means of which air is admitted inside the outer wall and into the

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perforated brick air flues, and there are 28 ventilators in the roof for the escape of the air.

The heating chamber measures 12 feet x 6 feet, and contains a small closed boiler stove. The hot water pipes are laid from it in a sunken channel between the filter and one of the outer longitudinal walls, with a return branch through each pair of perforated brick flues.

Colonel Ducat's experience is that microbial action ceases when the temperature on the filter falls below 37° F., and that nitrification is suspended when it rises above 120° F. The latter contingency is remote in England, but the former one is provided against by the heating apparatus which is used only in the cold season.

This standard filter has not yet been built or used as a whole, but it consists of a repetition of complete parts which have all been tried individually at Hendon.

The filter has its floor on the ground level, and looks like a low, windowless store.

The working of the filters is very simple after they have been inoculated and got into condition.

This is done by running the crude sewage on to them by means of the tipping channels for one hour and then shutting it off for an hour and repeating this 5 times a day for 14 days. During the next fortnight the dose is made continuous for 10 hours daily. In the third fortnight the filter is put to its full work day and night and receives its 100,000 gallons per day intermittently by means of the tipping channels in the normal manner.

The microbes which do the work are self-sown in the filtering material from the sewage itself. During the first part of the first fortnight the effluent from the filter is cloudy and has a distinct odour; the microbes, however, multiply and do better work as the days pass, and before the end of the fortnight the effluent is clear and odourless. When the dose is doubled in the second fortnight, the quality again falls off at the outset and gradually improves towards the end. When the sewage is first applied in its full quantity over the whole day and night there is a further falling off in quality, but by the end of the fortnight the filter is getting into condition. The effluent is then clear, and it gradually improves until at the end of three months from the first dose of sewage the filter is completely inoculated and is in prime condition. The sewage at the outset takes about 80 minutes to pass through the filter, but when in full working order and the filtering medium is coated with bacterial film 100 minutes are taken.

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After a filter is once in working order it is claimed that it can be left unused for months and will then resume its normal activity and efficiency in a day or two.

The filters at Hendon are fed with crude sewage from the bottom of the high level carrier which conveys the sewage to the precipitation tanks. The inlet to each pipe is protected by a screen of about ½-inch mesh which keeps back floating and large solids, but otherwise the sewage is crude. During rain the extra height of the sewage in the main carrier puts additional head on the pipe and thus causes a larger delivery to the filters than the 100,000 gallons per day. The variation of the dry weather flow likewise influences the head, and by that means the quantity delivered to the filter varies somewhat with the flow.

The original filter measures 15 feet x 12 feet on the surface of the filtering material, and has an area of 20 square yards and a depth of 8 feet. It has dealt with 4,000 gallons per day for seven or eight months continuously with satisfactory results.

The newer filter was started in April last and measures 15 feet x 12 feet=20 square yards—and has a depth of 10 feet. It has dealt with 4,000 gallons per day and its share of storm water, for about seven months almost continuously, allowing for occasional experiments and small structural alterations.

The sewage going to the filter on the 13th December last was thick, foul stuff, but the effluent appeared all that could be desired.

In the fil er under the roof there was a distinct smell of sewage, but at no other part.

The surface of the filtering material is not choked and has no scum on it and does not need raking over more than once in three months.

This filter is heated and had the tipping channels working.

It is connected to the main sewer by a 1½-inch pipe, which is about 9 feet long.

The analytical results of the process at Hendon on 6th October last are given by Mr. A. C. Houston, M. B., D. Sc., as follows:

Results stated in parts per 100,000.

	Crude sewage.	Filtrate.
Oxygen absorbed in 4 hours.....	14.72	0.78
Free Ammonia.....	8.70	0.30
Albuminoid Ammonia.....	1.60	0.094
Oxidized Nitrogen.....	....	0.477
General characteristics.....	A foul sewage emitting a most offensive smell.	As transparent and free from odour as an ordinary drinking water.

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PART II.

It will be seen from my description of what has been done as to the bacterial treatment of sewage in England, that up to the present time the trials have been on a somewhat small scale.

The complete Dibdin process at Sutton has dealt with 120,000 gallons per day out of a total flow of 400,000 gallons, the septic tank process at Exeter with a dry weather flow of 31,380 gallons per day, the Lowcock system with 7,680 gallons per day at Tipton, and the Ducat system with 4,000 gallons per day at Hendon.

Although these are meagre in quantity yet the results obtained warrant a hopeful view of the future usefulness of the processes, and I think the bacterial methods have established themselves in this country as very valuable means of treating sewage.

It is more than probable that experience will modify many of the views now held about them, and will also alter the methods of their application which now obtain.

But on the other hand certain definite results appear to be determined, and some of the limitations are revealing themselves.

In the Dibdin process for dealing with crude sewage it is evident that a large proportion of the matters which form sludge in chemical processes are converted into soluble forms by the bacteria, and that there is no solid residue produced.

This is a long step in advance, and will considerably reduce the working expenses of sewage treatment.

I advisedly, however, limit the results obtained in this direction to "a large proportion" because it is by no means proved that all the solids are disposed of. On the contrary there is evidence that some proportion remain in the filter and reduce its water content.

It has been found that a filter may have a water capacity of 50 per cent. of the bulk of the filtering material when first used, and that the water content diminishes rapidly by use in 8 weeks to 33 per cent., and then remains about that percentage when its output is a given volume per day. The deterioration of the water content is partly ascribed to the growth of bacterial substances on the surfaces of the filtering material and it is no doubt also partly due to the accretion of the mineral matters contained in the sewage remaining in the filter and which the bacteria are probably unable to liquefy.

When a Dibdin filter is given a long period of rest a recuperative process occurs which enlarges the water content, but in no case does the water content appear to return to its original percentage.

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At Sutton, after two years of hard work, the water content of the coarse filters has deteriorated to 19 per cent. There is reason to think that this is exceptionally low, but even if it should prove to be the case generally with the Dibdin filters, the difficulty is not a serious one. It would not be an expensive nor a difficult matter to have spare filtering material at hand to take the place of the choked material, and the operation of emptying and refilling a filter would not be a long one. There is a consensus of experience that choked material recovers by exposure to air without nuisance, and is serviceable again in six or eight weeks.

One of the drawbacks of the Dibdin filters when the outlet valve is first opened, is the opalescence of the filtrate. This is caused partly by the fact that the sewage in the underdrains has not been so long in close contact with the filtering material as that held in the body of the filter, and the bacteria, therefore, have not been so effective in their action upon it, and partly to the fact that when the valve is opened the full head of the filtrate causes a rush which carries with it some of the matters adhering to the filtering particles. After a few minutes the filtrate comes away clear and bright, and improves in appearanee till the end of the flow.

These causes can be removed to a large extent. If the bottom layer in the filter was of coarse material, and a large number of outlets were provided in one of the long sides of the filter, it ought to be possible to do without underdrains, for by the arrangement suggested there would be a much greater outlet provision than has yet obtained in practice, and the filtrate would not have such long distances to travel to them. Under such conditions it will probably occur that the waterway provided by the spaces between the coarse pieces will be sufficient to discharge the filtrate as rapidly as is desirable. If the valves controlling these outlets were actuated from a common shaft, there could be no difficulty in regulating the flow so as to make the quantity discharged per minute a fairly even one throughout, and of fixing it at such a speed that it would not wash out particles adhering to the material.

The Dibdin filters have a certain rigidity of operation which is a disadvantage in times of rain when the volume to be coped with is increased many times above the average. The cycle of work consists of four parts: First, the filling; second, the standing full; third, the emptying, and fourth, the aerating. It cannot matter as to the length of time taken for filling, and this may be expedited to any practical degree without disturbing the bacterial processes. The periods of standing full, discharging and aerating cannot, however, be much curtailed

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BALTIMORE SEWAGE

EFFLUENT OF SEWAGE

FILTERS

DRAWING No. 4

Width of daily dry weather flow of 100,000 gallons or 150,000 cubic feet.
Total is 13,000 cubic yards = 234,000 cubic feet and the intermittent three hours occupied by actual contact. The water contacts as three cascades two thirds of the daily flow is shown by this diagram. The depths of the bloody portions are in proportion

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without deranging the system, and this is a real difficulty which has not been fully met.

Closely connected with this question is that of the number of divisions into which a given content of filtering material may be most usefully divided, and as the practice here has not proceeded on any defined lines, I have gone into the matter and the results are shown on Drawing No. 4*.

I have taken the dry weather flow to be 1,000,000 gallons per day or 160,000 cubic feet.

The filter content for that quantity should be 12,000 cubic yards or 324,000 cubic feet. The water content may be taken at one-third, but for convenience of calculation it is put at 32.922 per cent., or 106,667 cubic feet, which is exactly two-thirds of the daily volume of 160,000 cubic feet. In this way each filter is charged three times in two days, or an average of one and a half times per day.

In dry weather the sewage does not reach the works in an even stream, but varies each hour. The flow is smallest at night and greatest near mid-day, and the extreme variation between the minimum and the maximum flow in the case of a town within say two miles of the disposal works is as much as six times. The curve of the hourly variations shown on the Drawing is a typical one in this country. The diagrams show the effect of dividing the filter content into 4, 6, 8, 10 and 12 equal parts. Starting to fill No. 1 at midnight, in the case where the filter content is divided into four, it will be found that the night flow does not charge it until 7.10 A.M., when the sewage is diverted into No. 2 and the increased flow fills it by 10.10 A.M., No. 3 is then used and is full by 11.50 A.M., and then No. 4 is brought into action and is charged by 2 P.M. Returning to No. 1, which was full at 7.10 A.M., it will be found by allowing it to stand full two hours and to empty in two hours, that it was cleared by 11.15 A.M. No. 4, however, was not full until 2 P.M., so that No. 1 had two hours 45 minutes for aeration before the sewage must be turned into it again. An examination of the diagram will show that this is the busiest part of the day's work, and that the other tanks have much longer periods for aerating; as for instance No. 4, which has 13 hours 10 minutes.

By dividing the filter content into six equal parts and again starting at midnight, it will be seen that No. 1 is filled by 5.50 A.M., and by giving it two hours to stand charged and two hours for discharge, it is empty by 9.50 A.M. As the content of the six is the same as the four just dealt with, the last filter is full in each case at the same hour, viz: 2 P.M., when No. 1 is brought into use again. It was empty, however, at

*Plate XII.

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10 50 A.M., and has thus been aerating for 4 hours 10 minutes. The effect of the smaller subdivision is to increase the time of aerating from 2 hours 45 minutes to 4 hours 10 minutes at the busiest time. The gain is entirely due to the shorter period taken to fill the smaller filter. Similiarly the maximum aerating period is extended from 13 hours 1 minutes to 14 hours 40 minutes, and at every intermediate step the aerating period is increased.

With 8 subdivisions the least aerating period is extended to 4 hours 35 minutes, and the greatest to 15 hours.

With 10 subdivisions the shortest aerating time is 5 hours, and the longest 15 hours 15 minutes.

With 12 subdivisions the aerating periods are extended to 5 hours 20 minutes as a minimum, and to 15 hours 20 minutes as a maximum.

I think it will be found in practice that 8 subdivisions are the most useful, because what little is gained by further subdivision is scarcely worth the extra cost of construction and operating.

With 8 equal parts it is possible to get through the day's work by using 7 only, but the minimum aerating period is then reduced to 2 hours 50 minutes. It may prove a convenience in practice to be able to use this possibility of throwing one filter out for a few days without unduly working the remainder.

There has likewise been confusion in the practice as to the *quantity* which can be dealt with by a given filter content. It was at first assumed that 160,000 cubic feet of sewage could be dealt with daily by 160,000 cubic feet of filtering material. This is true in one set of conditions and not in another.

On Drawing No. 5* I have set out a series of filters of the same content as before, namely, 324,000 cube feet divided into 8 equal parts, and I have shown the rotation when they deal with the dry weather flow of 1,000,000 gallons=160,000 cube feet per day, and also when dealing with a regular and even flow of 2,000,000 gallons or 320,000 cube feet per day, and with 3, 4, and 5 million gallons per day.

The curve of the daily flow is the same as in Drawing No. 4, and so is the diagram of the fillings for the dry weather quantity. The point to be observed is that the long times occupied in filling the filters make the output of 324,000 cubic feet of filtering material under the conditions I have assumed only 160,000 cube feet of sewage per day.

When, however, the variations in the flow are straightened out during rain and an even and regular quantity of 2,000,000 gallons or 320,000 cube feet per day is sent to the filters, the periods of filling are all of

*Plate XIII.

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BALTIMORE SEWAGE

DRAWING No. 5
1899

DIAGRAM OF FLOW IN SEWERS

dry weather flow of 100,000,000 gallons per day or 150,000 cubic feet, and that the additions of storm water occurring during storms are 134,000 cubic feet per second. Lastly, the water entering sewers in the vicinity of the Jones Falls sewer is 13,333.33 cubic feet, which equals 106,657 cubic feet per second.

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equal length, viz: one hour; and by giving 2 hours or standing full and 2 hours for discharging as before, 3 hours are obtained for aerating, making the cycle an 8 hours one. In this way each filter is used 3 times a day, and the output of the 8 is doubled, as compared with the dry weather flow. In this case 324,000 cube feet of filtering material deals with 320,000 cube feet of sewage.

When the flow is a regular one of 3,000,000 gallons per day the aerating period is reduced to 2 hours; when the flow is 4,000,000 gallons the aerating time is 1 hour 30 minutes, and when it is 5,000,000 gallons there is only 1 hour 12 minutes for that purpose.

I think it may prove possible to rotate the tanks up to three times the dry weather flow during rain, for the sewage is then diluted with twice its volume of water, and it is reasonable to think that 2 hours for aerating may recuperate the bacteria. Dealing with larger quantities intermittently, however, appears to be impracticable.

It is easy to see in the light of this drawing how the mistake occurred as to the output of the filters. The quantities dealt with in actual practice have been small fractional parts of the daily total, and the hourly variations have not affected the flow to the experimental filters. The quantity was thus an even and regular one, and I have just shewn that in those circumstances the output of the filter is twice as much as in the case when the dry-weather flow with its variations necessarily prolongs the times of filling and aerating.

Mr. Dibdin has within the last few weeks tried the effect of "streaming" the sewage when largely diluted with rain—that is, running it continuously through the filters—and the evidence is that bacterial activity is operative but considerably reduced.

It may be that the rain-water difficulty will be resolved by experiment and investigation, but at present it seems advisable to provide some auxiliary means of dealing with the excess above three times the dry-weather flow. This can be done by constructing a large rain-water filter of coarse material in which the excess may be separately dealt with.

I have found it difficult to appreciate the exact action of the bacteria in a Dibdin filter. The process is stated to be aerobic, but an examination of Drawing No. 5* will show that tank No. 1 is charged at the bottom for 8¾ hours, and it is certain that anaerobic changes are then brought into operation at the later part of that time. Dr. Sims Woodhead inclines to the view that the inferior appearance of the filtrate when first liberated is partly due to this dual action, for he is of opinion

* Plate XIII.

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that when the two classes of bacteria act side by side the best efficiency of each is impaired.

The effect of cold is to reduce the efficiency of the Dibdin filters a little. The sewage, in its passage through underground sewers is not brought into contact with the cold, and the few seconds it is exposed to the air in its passage from the sewer into the filter does not appreciably reduce its temperature. When in the filter there is a distinct rise in its heat, and the filtrate is certainly not colder than the sewage when it entered the filter. Similarly, the passage from the coarse filter to the fine one is so short that the cold does not do mischief.

There is some evidence to show that certain kinds of trade refuse, when mixed with sewage, are amenable to the Dibdin process. Tan refuse, vegetable dyes, brewery waste and the like are not detrimental, but it is very doubtful if strong mineral acids can be dealt with bacterially.

In the case of a sewage with a considerable admixture of trade refuse I would certainly experiment with it on a small scale before constructing a plant for the full quantity.

I have recently secured the approval of the Local Government Board to a scheme I designed for dealing with the sewage of a small seaside watering place on the Dibdin system, where the filtrate will be discharged into a tidal river. In that case, however, I can see my way to practically keep the whole of the rain-water out of the sewers.

It is too soon to express a final or very positive opinion on this system, but you will have gathered that I look upon it with considerable approval.

Septic Tank.

Coming now to the septic tank system we have an entirely different set of conditions from those operating in the Dibdin filters. This process seeks to employ the anaerobic bacteria in the septic tank and the aerobic ones in the filters, which are admittedly Dibdin filters.

The Exeter experiment, though on a small scale, deals with the varying dry-weather flow of a distinct district and with the rainfall up to 4 volumes. The water content of the tank at the outset was equal to 40 hours average dry-weather discharge. The flow of sewage into it is very variable as will be seen from the diagram on Drawing No. 2,* where it is shewn that the minimum flow at night is about one-sixteenth of the minimum at 11 A.M., while during rain the disparity is even more accentuated.

* Plate X.

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The solid matter of the sewage in its passage through the tank is either liquefied by the bacteria or remains behind as deposit. The change is undoubtedly putrefactive and the tank filtrate has an odour of decomposing sewage. This condition, however, is according to the bacteriologists a favorable one. The exposure to the air, which the tank effluent gets on its way to the filters is sufficient to supply it with the oxygen it needs, and it is then particularly suited to the aerobic action of the filter.

At Exeter there is a marked accumulation of solid matter in the septic tank, which the process seems unable to cope with. The deposit in twelve months equals one-sixth of the total content of the tank, and if it continues at that rate the tank will have to be cleaned out or the time of the passage of the sewage through it will be seriously reduced. Mr. Cameron is testing this phase of the process to destruction at Exeter. In 27 months the content of the tank has been reduced two-fifths, so that the water capacity is now 32,280 gallons, or practically a day's dry-weather flow, which means that the sewage is 24 hours in the tank on the average.

Of course the deposit may be cleaned out from time to time, but in that case the bacterial cultivations will be interfered with, and the sludge will have to be dealt with by some auxiliary means.

As shewing the obscurity of knowledge of the processes at work the different results as to deposit at Exeter and Yeovil are very curious.

At Exeter with domestic sewage the quantity of deposit is substantial, while at Yeovil with a mixture of domestic sewage and trade refuse the deposit is practically nil.

Various guesses as to the cause of this disparity have been made. It has been suggested that the trade refuse at Yeovil may favour the cultivation of bacteria capable of liquefying all the solids, but no proof of this is forthcoming.

It is also regarded as possible that the wider variations of flow at Exeter as compared with the more even flow through the septic tank at Yeovil account for the deposit in the former case. The idea underlying this explanation is that with an even flow an equilibrium is set up between the bacteria and the amount of work they have to do, which is disturbed when the variations of flow upset the balance. In the latter event it is suggested that when the maximum flow occurs the work to be done is in excess of the powers of the liquefying organisms, and that the more resistant parts of the solids accumulate as deposit.

Whatever the explanation may be, the fact itself prevents one predicating the results of dealing with a particular sewage by the septic tank system as regards deposit.

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Notwithstanding these difficulties and obscurities, I think the septic tank a useful instrument in sewage treatment.

The Dibdin filters, which are adopted by Mr. Cameron as the finishing part of the process, have already been dealt with.

I must point out that the automatic gear used for operating the filters has certain disadvantages.

By referring to Drawing No. 2* it will be seen that the slow flow in the night takes a little more than 10 hours to charge one of the filters, and that the one previously charged stands full all that time. It is certain that the aerobic action is interfered with by this long imprisonment of the tank effluent in the filter. Whether it is worth while saving the labour necessary for attending to the valves by hand at such a cost is one on which opinions may differ, but so far as I see it would be preferable not to use the present form of automatic gear.

There is one engineering advantage in the septic tank which ought to be mentioned, and that is the fact of the effluent flowing out at the same level as the incoming sewage, and thus the tank itself wastes no fall. In certain cases this may have a determining influence in the selection of the particular form of bacterial treatment for a given district.

With reference to Mr. Lowcock's aerated bacterial filters I need not enlarge on their capabilities. It would seem that the supply of air into the filter enables the bacteria to increase their activity, but the recent practice of resting the filter for 12 hours each day tends to show that natural aeration is necessary to the smooth working of the system. The original idea that the mechanical forcing of air into the filtering material would enable the tank effluent to be applied continuously has been modified by the adoption of the half-day intermittent working, and this result tends to support the Dibdin process of alternate fillings.

Ferozone-Polarite.

The Ferozone-polarite process first deals with the sewage by precipitation in tanks, and then passes the tank effluent through a filter made on waterworks principles but with a layer of polarite interstratified therein. There is something unexplained in the history of this process. At one time Hendon was the show place, then Huddersfield was quoted, Lincoln had its turn, and then Hyde was in favour. When one now goes to these places the process is either not completely followed or does not come up to the expectations held when it was adopted.

At the present time the Chorley works are the best. It is to be borne in mind, however, that the sewage there is very dilute, that a large por-

*Plate X.

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tion of the excreta does not enter the sewers, that the quantity of precipitant used is very large, that the tank accommodation is much in excess of the dry-weather flow, and that the filters are kept scrupulously clean.

The practice of using the filters at Chorley is entirely different from that followed at the outset. It was then held that 22 hours continuous work followed by 2 hours aeration for the revivification of the polarite was the right way, whereas now the tank effluent is applied intermittently every 20 or 30 minutes and the filter is given 8 or 9 hours aeration daily.

With a tank effluent like that at Chorley, which is clear and bright, it would be instructive to learn the effect of leaving the polarite out of the filtering material.

The results of the Ferozone-polarite system are so varying that one has a misgiving about it.

Seeing that it involves the whole plant for precipitating and pressing the sludge, and that polarite is an expensive filtering material, it is not too much to say that other processes equally efficient may be used at a less cost.

Ducat's self-acting bacterial filter has been tried on a very small scale and for a short time on a strong sewage which is almost wholly domestic, and one cannot therefore speak confidently as to its general application. The results obtained, however, are astonishingly good, and seem to show that accurate principles of cultivating the bacteria which deal with sewage have been applied. I think there is much promise as to its future, but beyond this I do not now care to express an opinion.

I have avoided the commercial side of these processes, but I may now briefly say that Dibdin's process is not subject to any patent, that Cameron's septic tank process is patented, but there is a question whether the protection applies to any part save the particular form of automatic gear for operating the filter, Lowcock describes his filter as a patent one, the Ferozone-polarite system is proprietary, and the Ducat filter is fully protected.

Part III.

Judging the Baltimore sewage problem from the bacterial standpoint at this distance there are two prominent features which immediately attract attention.

The first is the enormous volume of sewage per head per day which your Commission are compelled to provide for, owing to what I cannot help thinking to be an extravagant user of water, prevailing I know all over the States. This is four times what we have to deal with here, and it means, of course, that the works for similar cases would be four times

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larger with you than with us. With Dibdin filters an area of 2½ to 3 acres of coarse and a similar area of fine filter three feet deep would be the installation according to present ideas for a population of 30,000 (dry-weather flow, say 1,000,000 gallons,) in this country, whereas with you the area would range from 10 to 12 acres for each kind of filter. Similarly the septic tanks would be four times larger for equal populations.

This means that the cost of installing large structural works for these new and not fully developed processes is greatly increased in your case, and if failure should result the consequences would be serious.

There is also the consideration that diluted sewage like that of Baltimore may develop characteristics during bacterial treatment which have not appeared here. Presumably the task of cleansing the weak sewage ought to be easier than strong sewage, but this is by no means determined.

The second feature of Baltimore is one wholly in favour of the bacterial processes, and it is the fact that you have the sea or large flowing rivers into which the filtrate would be discharged. Such waters are fully oxygenated, and are therefore specially adapted for the reception of bacterial filtrates.

With a sea outlet or an outfall into a big river near to the sea I think the experience here would justify you in installing the Dibdin or the septic tank process for a small population of 10,000 or 20,000 persons, if an auxiliary means of dealing with the excess rain is provided.

It is a long step from the 120,000 gallons dealt with by the Dibdin system at Sutton, or from the 31,000 gallons dealt with by the septic tank at Exeter, to the 40 million gallons at Baltimore, increasing in the future to a possible 120,000,000 gallons, and one could wish there were a few intermediate examples.

The big problem is, of course, merely the multiplication of the smaller ones, and there ought to be no insuperable difficulty in applying what has been achieved to the larger case, but it would be prudent to proceed tentatively.

It may be that your Commission can devise a scheme for part of the city in such a manner as to test the capabilities of one or other of the processes, and which if the bacterial treatment did not answer, could be utilized for chemical precipitation and coke breeze filters.

I have the honor to be, gentlemen, your obedient servant,

JAS. MANSERGH,

Vice-President of the Institution of Civil Engineers, Member of the Institution of Mechanical Engineers, Fellow of the Geological and Meteorological Societies, Etc., Etc.

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BACTERIOLYTIC SEWAGE BEDS.

EXTRACTS FROM THE REPORT OF DR. SIMS WOODHEAD, F.R.S.E.
DIRECTOR OF THE RESEARCH LABORATORIES OF THE
CONJOINT BOARD OF PHYSICIANS (LONDON)
AND SURGEONS (ENGLAND.)

Introduction.

It may be well first of all to indicate the lines on which disintegration of the organic matter of sewage is broken down in nature; then to recapitulate briefly the principles on which the same process is carried on in the various methods of "filtration" or disintegration that I have had the opportunity of examining in the filter or bacteriolytic beds in this country.

In nature, as we know, the process of disintegration and putrefaction goes on slowly but very surely, especially in what is known as "living soil," where probably there is a process brought about by the action of various groups of organisms—anaerobic and aerobic acting symbiotically—going on.

On making a bacteriological examination of soil taken from very near the surface it will be found that the number of anaerobic organisms as compared with the aerobic is comparatively small. As we go deeper down, however, the proportion of anaerobic organisms is much larger, until we come to a layer in which practically only anaerobic bacteria are found, whilst deeper still there may be no organisms of any kind.

In nature the process of decomposition of organic matter goes on most readily in the superficial layers of the soil in which oxidation takes place very readily. This soil is a porous medium, usually well supplied with air and moisture and organic matter, and is a capital feeding-ground for micro-organisms, which, breaking up the materials contained in it, convert them by oxidation into substances which are capable of being utilized by plants. Most of the organic matter brought into contact with this aerated soil is broken down by the aerobic organisms

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it contains, some of the constituents of the organic matter as it is broken up being used by the bacteria, and others being, during the breaking down of the molecule, left in a nascent condition ready for oxidation by the air that has not been used by the organisms. The anaerobic organisms found in the deeper layers of the soil give rise to a second kind of decomposition. As the organisms, originally aerobic, have been washed deeper into the soil, they were no longer able to obtain free oxygen and have in time been compelled to develop the power of wresting oxygen by force, as it were, from the oxygen-containing bodies that come down to them from the surface, usually using part only of the combined oxygen, but setting free another part to be used up in the oxidation of other portions of the organic matter that still remains.

So completely do these two sets of organisms use up the food that is from time to time conveyed to the soil, that at a depth of about 12 feet no micro-organisms at all can, as a rule, be found. The relation of this process to the treatment of sewage is obviously one of extreme importance.

On examining the process by which natural manure is broken down in the upper layers of the soil, it is found that micro-organisms are here present in very large numbers and that the longer the soil is manured and the more it is used for the purpose of breaking down manure, the more active it becomes, for the reason that the micro-organisms not only increase in number, but they also become more energetic in the special direction in which they are called upon to exert their powers. There is a process of natural selection going on—those organisms that can live best under the new conditions flourish and increase in power and activity, and others which might interfere with their work are gradually ousted. If all sewage matter were solid and could be dug into the soil the best and most economical results would easily be obtained.

The difficulty of dealing with sewage matter in solution is no doubt considerable, but this difficulty is materially increased by the fact that the solid matter in it has also to be dealt with—a most difficult combination. In all processes hitherto used in the treatment of sewage, the sedimentation, separation and disposal of the solid matter has not only increased the cost of working, but has rendered the liquid part of the sewage less valuable as manure.

What takes place in nature may also be brought about under artificial conditions, and it is well when we are considering this question of the disintegration of organic matter—whether in nature or in artificially prepared filters—to determine what are the main factors of the process of decomposition and aeration.

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In the first place it is necessary to get all solid matter into solution; secondly, to attack the organic matter in solution by means of micro-organisms and so to break it up that the various elements of which this complex material is composed may be thrown into an unstable or nascent condition, so that the oxygen present may have an opportunity of entering into combination and of forming what are called oxidized substances; and in the third place to supply as large a quantity of oxygen in as short a time as possible for the purpose of providing for the needs of the aerobic organisms and of supplying a sufficient amount of oxygen to bring about complete oxidation.

These changes may take place in two perfectly different ways. In the first, oxidation takes place directly, all the nascent substances being satisfied by the oxygen of the air, and the splitting up of the organic matter being carried on by the aerobic organisms. In such a process which takes place in a porous soil well supplied with air and moisture, and also in water which is from time to time well saturated with oxygen, it will be found that little or no putrefactive odour is developed—the marsh gas, the sulphuretted hydrogen and other similar substances, as they are set free, rapidly combining with oxygen to form carbonic acid gas and water, sulphuric acid, etc., and the nitrogenous substances in a similar fashion becoming oxidized into nitrous and nitric acids. In the soil these acids combine with the various basic substances—lime, magnesia and the like—and are thus rapidly removed (from the chemical point of view) and the way is left clear for the formation of fresh batches of similar substances.

In anaerobic putrefaction, on the other hand, the process does not go on in this unobtrusive fashion. The anaerobic organisms, having as it were, to wrest their oxygen from the organic molecules, because there is no free oxygen present, set up a much greater molecular disturbance, and the products of the decomposition—such as sulphuretted hydrogen, marsh gas and ammonia—are thrown off in an unoxidized condition, and in the free form. They are no longer seized upon in the nascent condition, and thus, unless oxidized, become comparatively stable, giving rise to the putrefactive odours so characteristic of rapid anaerobic putrefaction.

The Action of the Dibdin Filters.

First of all it is evident that the sewage brings nutriment to the vigorous micro-organisms that are growing in the filter. In flowing into the filter the sewage probably takes up a certain amount of oxygen, but this cannot play any very important part in bringing about oxidation. As soon as the sewage comes in contact with the micro-organisms the

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organic matter is at once attacked by them whether they be aerobic organisms, which many of them are, especially those near the surface, or anaerobic organisms, those in the depth of the filter. As a result of the action of micro-organisms, some of which require carbon and nitrogen from the sewage and oxygen from the air, others of which take all they require from the sewage itself, the substances of which sewage is composed are broken down, and even those parts of the molecules not used by the micro-organisms are so re-arranged that in the presence of oxygen they are readily oxidized. When the filter is full, however, there can be little oxygen in the filter for the reason that the organisms are acting so vigorously that they utilize a certain quantity of the oxygen, whilst their products rapidly combine with the remainder, so that to the extent of the amount of oxygen that can be brought into such a filter, oxidation takes place. As soon as the oxygen has been used up the anaerobic organisms appear to come into vigorous action and to bring about a disintegration of both nitrogenous and carbonaceous substances. When the filter is emptied part of these altered substances pass out with the effluent, and are rapidly oxidized. A considerable quantity of fluid, however, remains in the filter, attached to the coke, and many of the products of the disintegration brought about by the micro-organisms remain in the immediate neighbourhood of these micro-organisms. As air is drawn into the filter when the filter is emptied many of these products (which are very greedy of oxygen) become oxidized, and it will be found that after such a filter has been standing "empty" some little time that a large quantity of carbonic acid gas and a small quantity of ammonia has taken the place of the oxygen, and it is evident that the process of oxidisation goes on actively while the filter is "empty;" as soon, however, as the oxygen is used up the filter again becomes an anaerobic bed, so that only a certain period of rest appears to be necessary in order that the best work may be got out of this filter. The main points to be borne in mind in the working of such a filter as this are (1) that there shall be a sufficient number of micro-organisms of high vitality and activity in the filter. Such a condition can only be attained by careful preparation of the filter bed, and it must not be expected that a coke breeze filter can be called upon to do work at once. (2) That the material supplied to it shall for the most part be in solution or in fine particles so that there may be no mechanical clogging, especially of the surface of the filter, as clogging of the surface must necessarily interfere with the access of oxygen to the deeper layers of the filter. (3) The materials presented to this filter must only have been subjected to the anaerobic process for a sufficient period to ensure the breaking up of the organic

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material into ammonia, as it appears that if the anaerobic process be prolonged beyond that point, increasing quantities of substances, which have a deleterious action on the micro-organisms both in the anaerobic tank itself and on the aerobic organisms in the coke filter, are formed.

The Work of the Anaerobic and Aerobic Organisms.

In all the "filter beds" I have examined I have been able to trace the influence of both anaerobic and aerobic bacteria; these two groups of organisms playing very important parts, perfectly distinct and occurring at entirely different stages of the process of disintegration.

It is evident that these two groups of organisms, if the best results are to be obtained in a confined space, must in the main be kept separate up to a certain point, at any rate. So far as we can see at present the anaerobic process is that which is first necessary; this should be allowed to go on up to such a stage that the nitrogenous substances are broken down and there is the production of ammonia; beyond this point this stage of the process should not be allowed to go, otherwise a number of substances appear to be formed in such quantities that they interfere in a most marked degree with the subsequent action, which it is desired to be brought about by the second group—the aerobic micro-organisms—to which organisms even in comparatively small quantities they appear to act as poisons. The anaerobic changes, usually spoken of as "putrefactive," require to be very carefully controlled, and it has been evident to me throughout that this anaerobic phase is often carried too far, with the result that the aerobic nitrifying changes are greatly delayed in the subsequent treatment of the sewage.

In my experiments I have taken the amount of ammonia formed as a measure of the disintegrative change that is going on, as one finds that the amount of ammonia produced gives a fair indication of the work that is being done in an anaerobic bed. Whilst the corresponding multiplication of the anaerobic organisms affords evidence as to the nature of the working activity of the bed it has been found in practice, as already noted, that if this anaerobic process is carried too far, that is, if the fixed oxygen from the organic material is all used up, there comes to be a re-arrangement of the nitrogenous material, and along with this there is a combination between the carbon, carbo-hydrates, the nitrogen of the nitrogenous material, the hydrogen from both, and the formation of distinctly poisonous substances—other than ammonia, marsh gas, carbon di-oxide and water—various carbon nitrogen compounds (amines, amides, etc.) and other combinations, in small quantities which, however, exert a deleterious effect on the further changes.

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It seems necessary, therefore, to determine by experiment the exact point at which one should attempt to stop the disintegration of sewage material without the presence of free oxygen, though so far as can at present be gathered a twenty-four hours' storage appears to give fair average results. If this process is stopped at the right stage it is found that it is an easy matter to continue the process of disintegration by aerobic organisms. The work done by these latter appears to be best indicated by the amount of nitrification that takes place: i. e., by the amount of nitrates that appears in the effluent from the bacteriolytic beds. Wherever the two processes—the anaerobic and aerobic—are too closely associated, even when the organisms can live side by side, it is found that the rate at which the individual processes are carried on is to a certain extent, interfered with; perhaps not as far as the ultimate results are concerned, but certainly as regards the rapidity of disintegration and nitrification. At the same time it must be remembered that even under the conditions above mentioned the two can never, so far as we can see, be kept perfectly distinct, although it is possible to obtain a high degree of anaerobic change, followed by well-marked aerobic change, by controlling and modifying the conditions under which the sewage is placed as it is being broken down. Taking first the action of the anaerobic organisms it has been shewn that in regard to the process of putrefaction and fermentation they appear to do a great deal of work by the expenditure of a comparatively small amount of energy. They disturb the molecular constitutions of the more highly organized products of life, now dead material, by wrenching out (or extracting), as it were, a few molecules of oxygen, or of other food material for their own use, thus producing a series of unstable substances: substances unstable partly because of their constitution and partly because they are in a nascent condition, and substances that are readily attacked by other free molecules, especially by those of oxygen. A complex molecule with one or two atoms removed immediately breaks up into smaller groups, or molecules, most of which have free bonds of affinity, to which oxygen becomes readily attached. It is for the reason that we have these nascent molecules that it is necessary to stop the anaerobic process before the re-arrangement becomes complete, and before all the available combined oxygen is used up. One or two molecules of nitrogen, hydrogen or carbon are withdrawn from a complex molecular group, which is thus left in an unstable condition, or there may be the formation of a number of re-arranged and incompletely combined molecules, any of which may undergo oxidisation. It is well known that there are certain organisms (especially those which attack cellulose) which appear to act almost entirely

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in the absence of free oxygen. After this process of violent disintegration or "revolution" the aerobic organisms appear to act to much greater advantage; unless, indeed, the sewage be so strong or the anaerobic process be carried so far, that too great an amount of ammonia is produced at once or the more poisonous products already referred to are formed in too great quantities. But this is not the only change that is going on at this stage of the process; a large part of the solid organic matter is peptonized; that is the substances at present insoluble are so far digested by the micro-organisms, or their products, that they are thrown into solution and so converted into a form in which they are more readily attacked; in addition to which, this solution of the solid matter does away with any clogging of the filtering media in the next stages of the process.

The aerobic organisms act on the organic matter in somewhat the same way, but being able to grow and multiply in the presence of free oxygen the whole conditions for oxidisation are naturally more favourable. We have the nascent molecules also formed in this instance because a certain amount of nitrogenous food is necessary for the nutrition of these aerobic organisms; the oxygen and hydrogen are probably derived from air and water, the carbon from carbo-hydrates. As a result of the separation of these carbon and nitrogen atoms we have a re-arrangement of the molecules just as in the case of the disintegration taking place in the anaerobic process. The molecules, with their free bonds are, of course, eager to take up oxygen. As there is plenty of oxygen available rapid and complete oxidisation is the result. We have an amount of "nascent" gases, etc., derived from the breaking down organic matter, the oxygen attacking these gases as they are set free and before they have time to subside into any other permanent or stable form.

As to the Septic Tank Process.

The difficulty of breaking down the solid matter of sewage so as to bring the constituents into solution has for long been one with which engineers have had to contend, but in the tanks provided in this and the Scott-Moncrieff systems, this difficulty has, to a large extent, been overcome, and overcome, apparently, by means of micro-organisms with the power of digesting such portions of organic matter as have not been dealt with in the human stomach and intestines. When the solid matter passes into the tank part falls to the bottom and part comes to the surface, whilst even that which sinks appears after a time to be brought to the surface, as gas in considerable quantity is set free or developed, the gas tending to break down solid particles and adhering to the smaller

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particles to carry them to the surface. On examining the sediment taken from the bottom of the tank only a small quantity of granular material and a few broken down fibrils could be found. The leathery mass at the the surface of the tank, which disappears in summer but in winter forms a covering of from 1 to 4 inches thick, contains a large number of bubbles of gas in its substance, while as seen from the inspection well, and from the manholes, streaks and areas of liquefaction of considerable size are to be seen on the upper surface. A similar process of liquefaction is evidently going on on the surface, as, although bubbles of gas are constantly rising, small particles of cellulose appear to be as constantly falling to the bottom of the tank, indicating that the solid matter is being broken down, some of the organic matter is being converted into gas; some is also being thrown into solution—for example, it was found that raw sewage contained 46.8 parts per 100,000 of total solids, whilst the tank effluent, as the result of the changes that had taken place in the tank, contained not less solids, but more (48.6 per 100,000), so that although there was undoubtedly a breaking down of organic matter, as evidenced by the presence of gas in the tank, there was still an increase of organic matter in solution.

The great function of this tank, however, appears to be the disintegration and liquefaction of the portions of sewage in suspension, a destruction especially of the cellulose which, falling to the bottom, remains longer in the tank and so can be more fully acted upon by the anaerobic organisms. It appears too that the urea is probably transformed into carbon dioxide and ammonia. There can be little doubt, from a consideration of the chemical analysis, especially of the tank effluent and of the filtered effluent, that a marked degree of disintegration occurs in the septic tank, and that considerable liquefaction takes place in the filter beds; for example:

TABLE 1.

	Total solids.	Oxygen consumed.	Free ammonia.	Alb. ammonia.	Nitrite.	N. as nitrate.	Total N.	Organic nitrogen.
Raw sewage:								
November 3, 4.....	46.8	6.56	3.6	1.40	0.0	0.0	7.4	4.4
Tank effluent:								
November 4, 5... ...	48.6	4.32	4.9	0.64	Trace.	0.04	6.24	2.2

from which it will be seen that the following changes have taken place in the sewage as it passes through the septic tank: (1), there is a marked

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increase in the total solids in solution or fine suspension; (2), there is a reduction of about 33 per cent. of the organic matter as measured by the oxygen consumed; (3), there is an increase of about 33 per cent. in the free ammonia; (4), there is a reduction of about 54 per cent. in the organic or albuminoid ammonia, or 50 per cent. in the organic nitrogen; (5), there is a slight production of oxidized nitrogen and a disappearance of a small amount of the total nitrogen. It is evident then that the sewage is considerably altered.

It was also found that although the dissolved carbonic acid was increased in quantity in the effluent there was still a giving off of carbonic acid gas, nitrogen, marsh gas and hydrogen from the surface of the tank. The increase in the amount of ammonia and of carbonic acid gas, which occurs in this tank along with the diminution in the amount of organic carbon and organic nitrogen indicates that even here the process of purification is commencing, and so long as these products can be got rid of without undergoing transformation into more poisonous products the anaerobic change is useful. As soon, however, as more complicated substances begin to be formed in larger quantities we have evidence that it is time to return to the aerobic fermentation; a point that must be carefully watched in any experimental work that is carried on. A second series of samples, analysed by Dr. Rideal, gave practically the same results as regards percentage purification. The anaerobic change is checked, as far as possible, at the point at which the tank effluent is passed over the small aerating weir. At this point, no doubt, certain gases escape, and others become more fully oxidized, so that we have some of the "waste products" oxidized before they come in contact with the filters.

It having been determined that certain chemical changes take place, it is necessary to see whether we have any collateral evidence as to the nature of these changes, and the means by which they are brought about. The first point was to determine whether these different sets of micro-organisms (anaerobic and aerobic) were present at the various stages of the process; whether, and (2), under what conditions, they undergo multiplication, and (3), whether it was possible by means of chemical and bacteriological examination to notice any association or relation between the two. By means of a series of bacteriological examinations it was found that large numbers of liquefying and non-liquefying anaerobic organisms, many of them gas-producing, were present in the crude sewage and in the septic tank, whilst small numbers of these same organisms were found in the tank effluent and in the filtered effluent.

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TABLE 2.

Number and Nature of Anaerobic Organisms found in Different Samples of Exeter Sewage.

	No. of liquefying organisms present per c. c.	No. of non-liquefying organisms present per c. c.
Crude sewage.....	300,000, some fluorescing and many of them gas-producing.	600,000 to 700,000.
Septic tank.....	200,000 to 300,000 (15,000 rapidly liquefying).	300,000 to 400,000.
Tank effluent.....	40,000.	120,000 to 300,000.
Filter effluent (end of filtration).....	100,000.	300,000.
Filter effluent, Well A, after running 3 minutes.....	70,000 (5,000 liquefying rapidly).	500,000.

It was especially noticed that in the crude sewage fluorescent and gas-producing organisms were present in greatest numbers, whilst in the septic tank there was a large number of rapidly liquefying organisms, the largest number of anaerobic organisms was separated from the crude sewage, and in addition to the fluorescing and gas-producing organisms, which were present in large numbers, the sulphur bacillus, a most characteristic sewage organism, was present in large numbers, the non-liquefying anaerobic organisms were also present in largest numbers in the crude sewage, and in the sewage taken from the septic tank the number of anaerobic organisms had certainly not increased, so far, at any rate, as they could be cultivated, but the number of rapidly liquefying organisms, i. e. those that break down or digest the gelatine very readily, had increased so much in number that it was difficult to examine the roll tubes because of the rapid liquefaction of the gelatine to which the tank effluent has been added. In the filtered effluent the number of liquefying anaerobic organisms had fallen very considerably; there was also a fall in the non-liquefying anaerobic organisms. This proportion was not maintained in another sample as regards the non-liquefying organisms, but the fall in the number of liquefying organisms was marked in every specimen examined. The aerobic organisms are also found in large numbers, in fact the largest numbers, in the crude sewage and in the tank contents, the highest number of non-liquefying organisms is found in the crude sewage and in the tank contents, whilst the number in the filtered effluent varied with the rapidity at which the filter was emptied.

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TABLE 3.

Number and Nature of Aerobic Organisms found in Various Samples of Exeter Sewage.

	No. of liquefying organisms present per c. c.	No. of non-liquefying organisms present per c. c.
Crude sewage.....	300,000 to 500,000.	3 to 5 millions.
Septic tank..... ...	150,000 to 200,000 (15,000 rapidly liquefying).	3 to 5 millions.
Tank effluent.....	300,000 to 400,000.	1 million.
Filter effluent (end of filtration).....	100,000.	900,000.
Filter effluent, Well A, after running off for three minutes....	30,000 (3,000 rapidly liquefying).	3 to 5 millions.

Having now determined that these organisms of both types were present, it was necessary to determine whether the various organisms separated would grow in the effluent or not. With this object in view a quantity of the filtered effluent was passed through a Chamberland filter and decanted into a series of large sterile tubes. These were seeded with samples of the various organisms, separated into pure cultures. Duplicate sets of such tubes were made in each case. Thirty c. c. of the sterile filtrate was inoculated from a gelatine culture of a special organism; plate cultivations were made from these dilutions at the end of twenty-four hours, by which time certain multiplication will have taken place and groups of organisms will have become broken down into their constituent organisms. Five days later plates were again made from the same tubes in order to determine what degree of multiplication had gone on in the interval, it being argued that should multiplication of organisms take place there must be some breaking down of the organic matter contained in the sewage. In every case but one multiplication had to be reckoned almost in millions, the numbers sometimes running up from 200,000 to 2 and 3 hundred millions. In one case, however, it was only from 600,000 to 20 or 30 millions.

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TABLE 4.

Shewing the rate of Multiplication of the Organisms separated from the Exeter Sewage when placed in sterile filtered Tank Effluent.

Source of Organism.	Control 24 hours.	5 days later.
Crude sewage No. 1.....	200,000 to 400,000.	5 to 10 millions.
" " 2.....	200,000.	200 to 300 millions.
" " 3.....	60,000 to 80,000.	30 to 40 millions.
" " 4.....	600,000 to 700,000.	1,000 millions.
" " 5.....	More than 2 millions.	1,000 millions.
Tank effluent " 6.....	600,000 to 700,000.	Several 1,000 millions.
" " 7.....	600,000 to 700,000.	20 to 30 millions.
" " 8.....	1,400,000 to 1,600,000.	40 to 50 millions.
Mixture of Organisms.....	200,000.	Very numerous.

These estimates only give general indications as to the nature of the processes going on, but they may be accepted, when taken in conjunction with the following figures, as especially shewing that most of the organisms grow with great rapidity in the sewage as it is found in the tank. It should be noted that there was the most rapid multiplication in the cases of samples Nos. 4, 5 and 6, and in the case of a mixture of organisms taken from several cultures; thus indicating that in these samples we must probably look for the most active chemical changes. The mixture of organisms caused rapid liquefaction of gelatine and coagulation of milk, this latter being followed by peptonization and liquefaction of the casein.

It is well known that nitrates and nitrites increase in quantity if sewage effluents are kept for some time before they are examined. In the tank effluent under observation nitrates and nitrites were present in very small quantities when perfectly fresh. In order to determine how far the increase of nitrates observed was brought about by different micro-organisms, samples of the tank effluent were filtered through Pasteur Chamberland filters into sterile flasks and tubes. After these had been kept for some time and the sterility of their contents tested, they were seeded with cultures of the various organisms, separated by the plate-culture method. Duplicate sets were made. These were allowed to grow at the ordinary temperature; one set being examined at the end of three, the other at the end of six days. In one series of experiments there was a very great increase in the amount of nitrates found. There was in nearly every case decrease of nitrites, this varying considerably in different cases, but being most pronounced where the nitrates were highest. The results obtained, however, correspond fairly

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in all three sets of specimens; the process of nitrification or the formation of nitrates going on with considerable activity although the sterile filtrate remained absolutely stationary.

TABLE 5.

Shewing amount of nitrogen as nitric and nitrous acid in sterile filtered tank effluent and in the same effluent to which various micro-organisms and mixtures were added, growth being allowed to go on for six days.

	N. as nitric acid per 100,000 parts.	Percentage increase of nitric acid.	Relative amount of N. as nitrous acid, 10 being taken as the standard of measurement.
Sterile tank effluent.....	0.661	0	10
Do. + organisms from crude sewage No. 1.....	1.417	+114 p. c.	6
Do. do. No. 2.....	1.386	+109 p. c.	10
Do. do. No. 3.....	1.291	+ 95 p. c.	4
Do. do. No. 4.....	1.417	+114 p. c.	6
Do. do. No. 5.....	1.638	+147 p. c. E.	1 E.*
Tank effluent No. 6.....	0.3	— 55 p. c. O.	Excessive O.*
Do. No. 7.....	0.819	+ 24 p. c.	8
Do. No. 8.	0.567	— 15 p. c.	8
Mixture of 3 organisms.....	1.449	+119 p. c.	8
Mixtures of all the organisms separated.....	1.23	+ 86 p. c.	10

* Compare these figures with those similarly marked in Table 6.

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TABLE 6.

Second series made with two sets of sterile tank effluent, one of which contained a higher proportion of nitrogen as nitric acid per 100,000 parts than the other. The control, i. e., the sterilized fluid in the case of Sample A, contained only 0.187 per 100,000 parts. Sample B contained 0.325.

	Sample A.				Sample B.			
	N. as nitric acid per 100,000 parts after growth of		Percentage increase or decrease of nitrates.		N. as nitric acid per 100,000 parts after growth of		Percentage increase or decrease of nitrates.	
	3 days.	6 days.	3 days.	6 days.	3 days.	6 days.	3 days.	6 days.
Crude sewage No. 1	0.200	0.200	+ 7 p. c.	+ 7 p. c.	.....	.....	.....	.....
" " 2	0.162	0.300	—13 "	+60 "	.....	.....	.....	.....
" " 3	0.09	0.250	—53 "	+33 "	.....	.....	.....	.....
" " 4	.200	.....	+ 7 "	.....	.....	0.287	.....	—22 p. c.
" " 5	.....	.....	.....	.....	0.225	0.387	—31 p. c.	+19 " E.*
Tank effluent No. 6	.....	.....	.....	.....	0.287	0.150	—22 "	—54 " O.*
" " 7	.....	.....	.....	.....	0.130	0.269	—60 "	—19 "
" " 8	.....	.....	.....	.....	0.225	0.265	—31 "	—19 "
Mixture of 3 Organisms	0.218	0.265	+16 p.c.	+41 p. c.	.....	.....	.....	.....

* Compare these figures with those similarly marked in Table 5.

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In one or two cases a pure culture of a single organism gives as high an amount of oxydized nitrogen as does inoculation of the whole or several organisms contained in the effluent. It seems to be necessary for the disintegration of cellulose and other resistent organic matter, that it should be in contact in concentrated form with the micro-organisms in the tank for a lengthened period. Owing to the slow flow of the sewage through the tank the solid matter is not stirred up except by such gas as is formed, and consequently only lighter particles that have been partially decomposed are brought to the surface after they have been settled.

The Dibdin Filters when dealing with Septic Tank Effluent.

I have examined samples of the coke breeze; samples of the tank effluent before it goes into the filter, and samples of the filtrate effluent, with the object of determining approximately the number and the general nature of the organisms found at these various points in the filter beds, especially at the surface.

Aerobic organisms are here present in considerable numbers, but anaerobic organisms are also present, probably washed over from the filter tank; in the deeper layers of the filter beds these latter are, as it were, indigenous. It is evident from the conditions under which the two processes in the tank and in the filter are carried on, that there are both facultative aerobes and anaerobes amongst the micro-organisms doing the work, and that although it is possible to group the processes generally it is impossible under present conditions to draw a sharp line of determination between the two sets of organisms. When the sewage comes from the tank it is, as we have seen, first aerated and then passed into the filter so that the bulk of it in its passage downwards comes in contact with a considerable surface of the filtering material, trickling down slowly and carrying with it the oxygen that has already been taken up and intangling a still further amount to be immediately utilized. In summer, when there are periods of dry weather followed by heavy rains and then again by a dry period, the stay in the filter would not correspond to the strength. Owing to the time that it takes for the sewage to pass through the tank it is probable that this full period might be very materially shortened, and that the filter might be discharged as soon as the oxygen contained in it is used up, as it has been found that even during the period that the filter is filling the proportion of carbon dioxide is enormously increased even in the upper layers of the filter; this in itself affording strong proof that the organisms in the filter are extremely active, and are attacking the carbo-hydrates and break-

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ing them down rapidly. It must, therefore, not be assumed that the whole, or even the greater part, of the changes take place whilst the filter bed is full; indeed it appears that the micro-organisms on the surface of the filtering material are probably more active during the stage that air is being drawn into the filter as it is emptied from the bottom than during the time that the filter is full. The process must then be looked upon as mechanical only in so far as the fine filtering material attracts all suspended matter to the mass of actively growing micro-organisms on its surface. In addition to this a considerable part of the organic matter in solution is taken up by the layers of micro-organisms as the filtered material slowly trickles over the exposed surfaces of the filtering medium. If there could be an excess of oxygen kept in the filter there seems no reason to doubt that the whole of the organic matter might be converted into nitrates and nitrites; matter which at present appears to be converted rather into ammonia, and perhaps some free nitrogen. One of the great advantages of emptying and refilling the filter is that the products of deposition, which might interfere with the activity of the aerobic organisms are regularly washed away, each discharge of the filter removing these products and leaving the organisms free to deal with the next batch of sewage as soon as it is thrown in, so that here the conditions for the continuous activity of the micro-organisms are exceptionally favourable. The sewage brings a large quantity of food supply, mostly insoluble and rapidly attacked, whilst at each emptying of the filter the effete products, which usually play such an important part in interfering with the activity of the micro-organisms, are washed away.

These effete products are the nitric and nitrous acids, carbon dioxide in solution, ammonia in solution and some of the gases already referred to. It must be remembered in this connection that the effluent must not be judged on the basis of a drinking water; it must be judged rather on the amount of readily oxidisable materials that it contains, and on the facilities that there are for rapid oxydation of these substances into those of more stable character. Whether the effluent be thrown on to land or discharged into well-oxygenated water (especially if this be tidal or sea) the criterion as to the fitness of the fluid to be discharged must be the proportion of oxidisable substances that have taken the place of the original organic matter in the sewage and the relation of nitrogen to chlorine must always be considered in connection with the proportions of oxidisable and non-oxidisable nitrogen. If the proportion of oxidisable or oxidised nitrogen be low, the filters are not doing their work properly; if the proportion be high the mere total amount of nitrogen is not of great importance, as the filters are doing what is required of them. They are breaking down the organic matter into such a condition that

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it will rapidly become mineralized in the soil or in well-oxygenated water. The results of oxydation are so marked that a more complete saturation of the tank effluent with oxygen before it is allowed to pass into the filter might accelerate the process. This might be done by increasing the length of the channel and increasing the number of weirs. Such solids as remain in the tank effluent are kept back on the films covering the coke breeze, and at the same time organic matter in solution appears to be taken up by the organisms in these films as the fluid trickles through the filter. The organic matter thus brought, practically serves as fresh food for the micro-organisms by which it is disintegrated; part of it being used up by the organisms and part passing into solution, or passing off in the form of the various gases found in the filter. These changes go on so long as any oxygen remains in the filter, whether it be full or empty of sewage. Naturally, therefore, when the filter is full there can be no access of fresh oxygen from the outside, and what is there is soon used up as the filter is empty, therefore fresh oxygen is brought, and at the same time the effete products, which prevent further action of the micro-organisms, are washed away and the organisms are left free to act upon the next batch of food that is supplied to it. The filters, therefore, are probably acting most actively during the period that they are empty. Peptonisation, liquefaction and digestion of the solid organic matter goes on very rapidly, both in the septic tank and in the filters. The filter beds do not get clogged, and will run almost continuously (intermittently) so long as the period necessary for full aeration is allowed between each discharge of tank effluent. Admitting that the general indications go to shew that the filter only does its best work when the number of micro-organisms deposited on the surface of the filtering material has become sufficiently large and when they receive a full supply of oxygen, it appears probable that the organisms carrying on the work of disintegration of sewage are almost entirely of a non-pathogenic character. The organic matter in the filtered effluent is in such a highly unstable and rapidly oxidisable condition that it appears to be suitable for discharge on to land or into a large volume of well-oxygenated water, especially when such water is not to be used for drinking purposes.

As to the Influence of Variations in the Flow of Sewage.

As soon as the whole of the sewage from any area came to be treated it was evident that it was impossible to obtain the best results unless the flow could be made regular, as the filter beds would have to be made capable of doing the full amount of work required of them

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during the period that there is the greatest flow of sewage; during the remainder of the day they would be working with a great waste of energy, while if, on the other hand, they were constructed for the purpose of taking the average amount of sewage, they would, at one part of the day, be overworked and sending out a bad effluent, whilst at other parts they would be called upon to do less than they could actually perform. It is not as if it were possible as in the case of chemical precipitation or chemical treatment of any kind, or even in irrigation work, to increase the amount of chemicals as the sewage increases, or throw the sewage on a larger area of land. When a filter bed becomes thoroughly ripe, that is, when the micro-organisms in it are acting most efficiently, there is one quantity of sewage and one alone from which the best and most economical results will be obtained; this quantity should always be kept running on to the filter beds.

General Conclusions.

It is evident from all these observations:

(1.) That these biological beds, whether anaerobic or aerobic, all require a certain period during which the micro-organisms may multiply and become active.

(2.) That if the best work is to be got out of these "filter beds," they should be kept in as stable a condition as possible, i. e., the anaerobic filter should always be worked under anaerobic conditions, and the aerobic filter under aerobic conditions. Otherwise the special organisms concerned in the special processes become weakened and the filter no longer does its work properly.

(3.) This being the case it is obvious that whatever form of filter be used, it must be gradually worked up to its best, and then the conditions under which this "best" is obtained, carefully maintained.

(4.) It does not seem to matter what form the anerobic bed may take, and twelve hours in a full sewer was in one case quite sufficient to bring about the necessary anaerobic changes—liquefaction and ammonia formation; but the conditions under which the aerobic changes are carried on should be more carefully attended to, and so far as my experience goes, the separated well aerated trays give better results than any of the other filter beds examined, though I believe that Lowcock's or Ducat's methods may, other things being equal, give extremely good results. Complete and rapid aeration in the presence of numerous and vigorous aerobic micro-organisms should certainly give the best results, especially if the constituent molecules of organic matter can be presented

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to the action of these aerobic organisms very quickly after the disruptive anaerobic process has been initiated.

(5.) Sewage to be efficiently treated by the bacteriolytic method should not be worked upon in too concentrated a form, whilst dilution between the two stages of purification and then again after the second process will always ensure more rapid oxidation of the products of decomposition.

(6.) One of the means that we have of learning indirectly the power of doing liquefying work in the disintegration of the organic matter is to determine the relative number and activity of the liquefying organisms that are met with in the aerobic and anaerobic areas. Speaking roughly, and taking several analyses as the basis for calculation, one finds that the rapidly liquefying organisms are, anaerobic to aerobic, as three to one. That is, taking a hundred anaerobic organisms, one would find that on an average thirty of these are actively liquefying organisms, i.e., they have the power of peptonising gelatine, and probably also of digesting similar nitrogenous substances; whilst of one hundred aerobic organisms only ten would be endowed with a similar power of digesting this organic matter. This is probably the reason that the anaerobic organisms are more useful in the early stage of the process, where it is necessary to throw the solids into solution; for, until this state is reached, it is impossible to attempt to act rapidly upon the sewage in bulk by means of micro-organisms.

G. SIMS WOODHEAD.

24th December, 1898.

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APPENDIX G.

"THE PURIFICATION OF SEWAGE BY BACTERIAL OXIDATION."

This name is given to a protected process developed by the late Col. Geo. E. Waring, Jr. The process is based upon results obtained by experiments made by him at Newport, Rhode Island, in 1894. Without describing these, the conclusions reached by him may be summed up as follows:

1. The suspended matters in sewage may be retained by straining through some coarse material and subsequently completely destroyed by aeration.

2. If conducted intermittently the process may be carried on indefinitely without renewal of material, and the effluent will compare with that from chemical precipitation plants.

3. By passing the effluent constantly through aerated filter beds of proper design, "practically all of the dissolved organic matter in sewage can be removed, and purification to a drinking water standard can be obtained."

Since these experiments were made, disposal works on this plan have been installed at Willow Grove Park, near Philadelphia; Tuxedo Park, N. J.; Homewood, a suburb of Brooklyn, N. Y.; Albion, N. Y., and East Cleveland, Ohio.

The Willow Grove plant serves a park of that name established by the Philadelphia Traction Co. as a suburban pleasure resort. Through the courtesy of Mr. John B. Parsons, President and General Manager, and Mr. W. S. Twining, the Chief Engineer of the Company, a visit was made to inspect the plant.

Designed for a flow of from 80,000 to 100,000 gallons of sewage per day, the maximum rate up to the visit referred to, had approximated 160,000 gallons per day. The amount fluctuates very greatly, depending on the number of persons who happen to be attracted to the place for the fraction of a day, and, as it comes principally from afternoon and evening visitors, and with no trade refuse, it cannot be classed as a normal sewage.

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It is delivered first to a receiving well, (Plate XIV.,) having a capacity of some 12,000 gallons, where it passes through two sets of screens, the first consisting of ⅝-inch iron rods spaced ½ inch apart, and the second a netting of galvanized iron with a ¼-inch mesh. The former intercepts all coarse papers, rags, lemon-peels, etc. The finer screens were said to require cleaning but about twice in the season of about four months, while during that time about a foot in depth of sludge accumulated in, and is removed from, the bottom of the well.

From the receiving well the sewage is pumped to distributing tanks placed above the roof of the well-house. These serve to equalize the flow by storing sewage received when the discharge is heavy, and delivering it during hours of minimum flow.

From the tanks the sewage flows to what are termed *strainers*. There are three of these, 22 feet by 32 feet in plan, each divided by a partition wall into two equal parts; suitable openings along the bottom of these walls leave a certain space through which the sewage may flow. Both parts of the strainer are filled with stone, broken to sizes of from ½ inch to 1 inch, to a depth of two feet, under which are laid several lines of hollow tiles with open joints, which collect the effluent. Entering the outer compartment of one of these strainers, the sewage passes down, depositing its sludge on the broken stone by the way, and then under the partition wall and up through the other compartment.

The effluent, which is now practically deprived of its solid matter, passes into perforated channels by which it is distributed over the surface of *aerators*, so called, of which there are four, 24 feet by 32 feet in plan. These are filled with coke crushed to the size of peas, covered with a layer of sand to a total depth of five feet. The coke rests upon a layer of hollow tiling which collects the filtrate. The tiles are laid close, but without cement, over the entire floor of the aerator. The filtrate is, after passing through a well used for testing purposes, delivered into an ornamental pond, whence the water is pumped for sprinkling the roadways and lawns.

The three strainers are used in rotation, one filling while the next is emptying, and the third lying idle or being cleaned. After a strainer is clogged with sludge it is cut out from the others and drained; then air, under a pressure of about three ounces, is forced through the hollow drain tiles, and finds its escape through the sludge-covered stone, permeating it and oxidizing the impurities, so that it is left comparatively clean, dry and without offensive odor. A certain amount of sediment appeared to remain on the broken stone, but more in the nature of dry earth than sludge. The water which has been drawn off from the strainer is added to the crude sewage and undergoes treatment again.

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Plate XIV

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Sewerage Commission

Warning System of Galveston

City of Galveston

Willow & Rose Streets

1899

Scale of Feet

Sewerage Commission { Theodore Cutler, S.H. Hamilton, E.F. Smith.

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The flow through the coke filters or aerators is continuous, and, as in the strainers, the drain tiles serve as carriers for the compressed air. This is forced up through the filtering liquid, stimulating the bacterial action by which the organic matter remaining in solution is oxidized, and controlling by its pressure the rapidity of filtration.

The effluent when seen was slightly opalescent, but is said to be frequently taken from the collecting well as a beverage with no harmful results.

There are air vents running up through the top layer of the aerators to prevent a disturbance of the filtering material from an excess of air pressure. The air appeared in bubbles fairly distributed over the surface of the aerators where there was a considerable growth of green algae.

But two men are required to attend to the work during the busy season.

The Willow Grove Park plant serves as a type of this system, but, being the first of its kind, experience has indicated improvements as to details by the adoption of which a yet higher efficiency, it is claimed, may be attained. It has been suggested as preferable, for instance, to provide independent ducts for the compressed air and the effluent from strainers and aerators. The relative proportions of the two parts of the strainers, their depth and the depth of the aerators are also points concerning which there is probably required more definite knowledge, to be had only by experience, in order to obtain the best results.

Experience, too, appears to be lacking in order to predict with any certainty the cost of operation. With the Willow Grove plant the power required for the fans and pumps was supplied from the Traction Company's power-house, and so its cost would be no criterion for other works; but aside from this the expense was not great, probably less than $1,000 for the season.

Although similar in many respects to Lowcock's system, it differs from the latter in that it deals with crude sewage, the sludge as well as the dissolved impurities being disposed of by forced aeration, whereas the Lowcock filter would clog if the solids were not previously disposed of by chemical precipitation.

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APPENDIX H.

THE PENNSYLVANIA SANITATION COMPANY'S METHOD OF SEWAGE PURIFICATION.

This process, which consists in a combination of aeration and filtration, may be best illustrated by describing the plant in use at Reading, Pa., where, so far as we are informed, is the only establishment as yet undertaken by this Company. Through the courtesy of the City Engineer, Mr. Samuel S. Hoff, an inspection of the plant was recently made and data concerning its operation obtained.

The population of Reading today is estimated at between 70 and 80 thousand, of which perhaps one-tenth only are, as yet, connected with the sewers. The separate system of collection has been adopted and the volume now treated averages about two million gallons per day.

The sewage enters one of two screen chambers, each 20 feet in diameter, at the pumping station, where it is distributed from the 54-inch sewer upon a layer of coke broken to a size of from 2 to 3 inches. This layer is 12 inches thick and is enclosed between gratings of wrought-iron bars. The upper grating may be raised in sections for the removal and renewal of the coke. It is covered with a wire netting, which intercepts such grosser matter as finds its way to the pumping station.

Each of the two chambers contains 4½ tons of coke. This is used until clogged so as to impede the proper flow of sewage, and is then removed, drained, dried by steam, mixed with bituminous coal and burned under the boilers. If left exposed for any length of time it soon becomes very offensive. From 18 to 20 tons of coke are used in this way per month.

From the screen chambers the sewage is pumped through a cast-iron main under the Schuylkill River to the filters. There are two of these, one supported above the other. The upper filter consists of ten beds, 25 x 50 feet in size, and is composed of 14 or 15 inches of sand laid on 6 inches of cinder from ½ inch to 2 inches in diameter. The whole is supported by a grating of ⅞-inch wrought-iron pipe.

The force main runs along and above the centre of the filter and discharges the sewage through ordinary gate valves to laterals consisting of 8-inch galvanized iron pipes placed between the separate beds, and these in turn discharge to semi-circular galvanized iron channels 6 inches in diameter, spaced 4 feet apart. The sewage flows over the edges of these channels onto wooden gratings partly covered with sheet-iron,

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which serve to distribute the sewage over the sand and prevent the washing of its surface.

The sewage is delivered continuously to about six of the ten compartments until, with a depth of a foot above the filter, the flow is too greatly impeded in any compartment. This is then drained, a thin slice taken off the sand by a shovel, and then the whole well spaded and re-surfaced with fresh sand. This is generally found necessary after about 30 hours application of sewage.

Passing the upper filter, which is supported on cast-iron columns, the effluent drops 10 feet as a shower to the surface of the lower filter. This is composed of 2 feet of sand on top of 8 inches of coarse slag, the whole resting on a bed of concrete. Drainage channels averaging 13 inches by 8 inches cross this bed at intervals of 12½ feet to afford aeration as well as drainage. They are covered with iron gratings and terminate at their upper ends with vent pipes extending through the surface of the filter. The effluent passes from these channels to a concrete effluent channel, which conveys it to the river bank. The lower filter is cleaned twice a year, which operation takes some 20 hours, and during this time the sewage passes to the river untreated.

The total area covered by each filter is 0.287 acre, so that the average rate of filtration now approximates 7 million gallons per day per acre of each filter.

The effluent from the filter to the river appeared limpid and pure, and the channel, including a paved slope to the river water, was clean and with but slight evidence of sewage fungus among the green mosses just at the end of the channel. A sample taken in a glass showed a small amount of fine flocculent matter, but was without other evidence of impurity, and was said to be occasionally used as a beverage.

Unfortunately, no analyses have been made of the effluent while working under present conditions, so that the only ones available are not considered of sufficient value to insert here in full, although it may be stated that in the two analyses made 10 and 20 days, respectively, after the works were put in operation the reduction in albuminoid ammonia and bacteria were as follows:*

	Sample I.		Sample II.	
	Albuminoid Ammonia.		Albuminoid Ammonia.	
	Parts per 100,000	Bacteria.	Parts per 100,000	Bacteria.
Crude sewage.....	0.140	27,232.8	0.730	49,867.3
After coke screening.....	0.090	19,152.4	0.060	16,542.7
" passing upper bed....	0.020	516.6	0.025	232.6
" aeration	0.015	126.0	0.040	81.2
" passing lower bed....	0.025	22.0	0.055	0.2

*See Engineering News, January 27, 1898.

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A marked purification is seen to result from the preliminary process of straining, chiefly due, in all probability, to the solids retained in the coke rather than to any actual alteration in either the sewage or sludge. Considering the rate of filtration, if correctly given at 2 million gallons per day, as claimed at the time the samples were taken, the results of the above analyses appear remarkably satisfactory. The destruction of bacteria indicated as occurring during the fall of 10 feet from the upper filter to the other is believed to be anomalous and misleading, and Messrs. Emil Nuebling (Superintendent and Engineer), and Allen Hazen (Consulting Engineer), in a report to the Water Commissioners of Reading, say: "We have not been able to discover the slightest reason for supposing that any bacterial purification is effected in this way."

The cost of the filtration plant complete, excluding pumping plant, force main and land, was about $90,000, and the annual cost of maintenance has been about $9,000.

During the coldest weather of the past winter, when the thermometer remained about 14° below zero for several days, no ice formed on the filter beds except where in contact with the iron work, and this was easily removed. For the purpose of excluding frost the sewage was applied continuously to all ten beds, being interrupted only as one or more required cleaning. It was delivered on the filter with a temperature of 42°, and up to the time of reaching the effluent drains it had only fallen to 40° Fahr.

It may be added that there was no appreciable odor about the works.

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APPENDIX I.

THE SCOTT MONCRIEFF SYSTEM OF SEWAGE TREATMENT.

This process has attracted much attention recently from the very favorable results which analyses of its effluents have developed in the hands of competent and reliable chemists.

The first installation of this system was at Ashtead, England, where the experiments, observations and analyses referred to were had. We learn that a plant has recently been established at Caterham, England, but of this we have not been able to obtain reliable information, nor was Mr. Mansergh more successful in this regard.

We are dependent, therefore, for our description of the process upon the facts we have been enabled to collate from correspondence with which we have been favored by Dr. G. Sims Woodhead and Dr. Samuel Rideal, of London, and from such descriptions as we have found in various published articles in technical journals.

Its essential features consist first in what is termed a "cultivation tank." This tank is filled to a depth of 14 inches with a coarse material described as flint chips. To the under surface of this material is introduced the collected sewage, which has previously been freed by deposition from grease and sand. The sewage passes through this material by continuous upward flow and is here exposed to the action of anaerobic and liquefying bacteria. Thence it is conducted through a suitable channel to a series of filtration trays through which the partially treated sewage passes by gravity.

These trays in the Ashtead installation were arranged in a series of nine, superposed on each other by a suitable system of framing.

Each tray, seven inches in depth, with perforated bottom, contained six inches of broken coke of a size that would pass through a one-inch ring.

Between the bottom of each tray and the surface of the filtering material in the one beneath it, an interval of from two to three inches was left. As the sewage discharged over the surface of the upper tray passed in thin streams through the vacant spaces and trays beneath the first, it was exposed at each interval to a degree of aeration and

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then to a new filtration, so that the process was carried on progressively, as it were in distinct zones—an examination of the effluent from each tray clearly revealing the progress of the purification as the flow proceeded.

We append hereto a table giving chemical analyses of the effluents from the several successive trays, together with a graphic diagram by Dr. Rideal, being an excerpt from his paper in the Journal of the Sanitary Institute, vol. xix., part iv., showing the progressive oxidation of the nitrogenous matter.

A remarkable feature of this process is that these surprisingly satisfactory results are obtained in something less than the ten minutes required for the passage of the sewage through the several trays.

TABLE SHOWING SUCCESSIVE STAGES OF BACTERIAL MINERALIZATION:*

Parts per 100,000.

Sample From	Chlorine.	Ammonia.		Nitrogen.	
		Free.	Albuminoid.	Nitrous.	Nitric.
Tank	9.00	12.50	1.50	0.00	0.120
1st Tray	9.00	10.50	1.25	0.99	0.096
2d "	8.50	9.00	1.00	0.90	0.480
3d "	8.50	5.00	0.60	0.78	1.870
4th "	8.00	4.00	0.35	0.66	2.760
5th "	7.75	1.50	0.15	0.48	4.680
6th "	8.00	1.75	0.35	0.51	4.416
7th "	7.50	0.35	0.30	0.00	6.600
8th "	7.50	0.20	0 65	0.00	7.320
9th "	7.50	0.25	0.60	Tr.	9.000

*Engineering Record, Vol. XXXVIII, p. 562.

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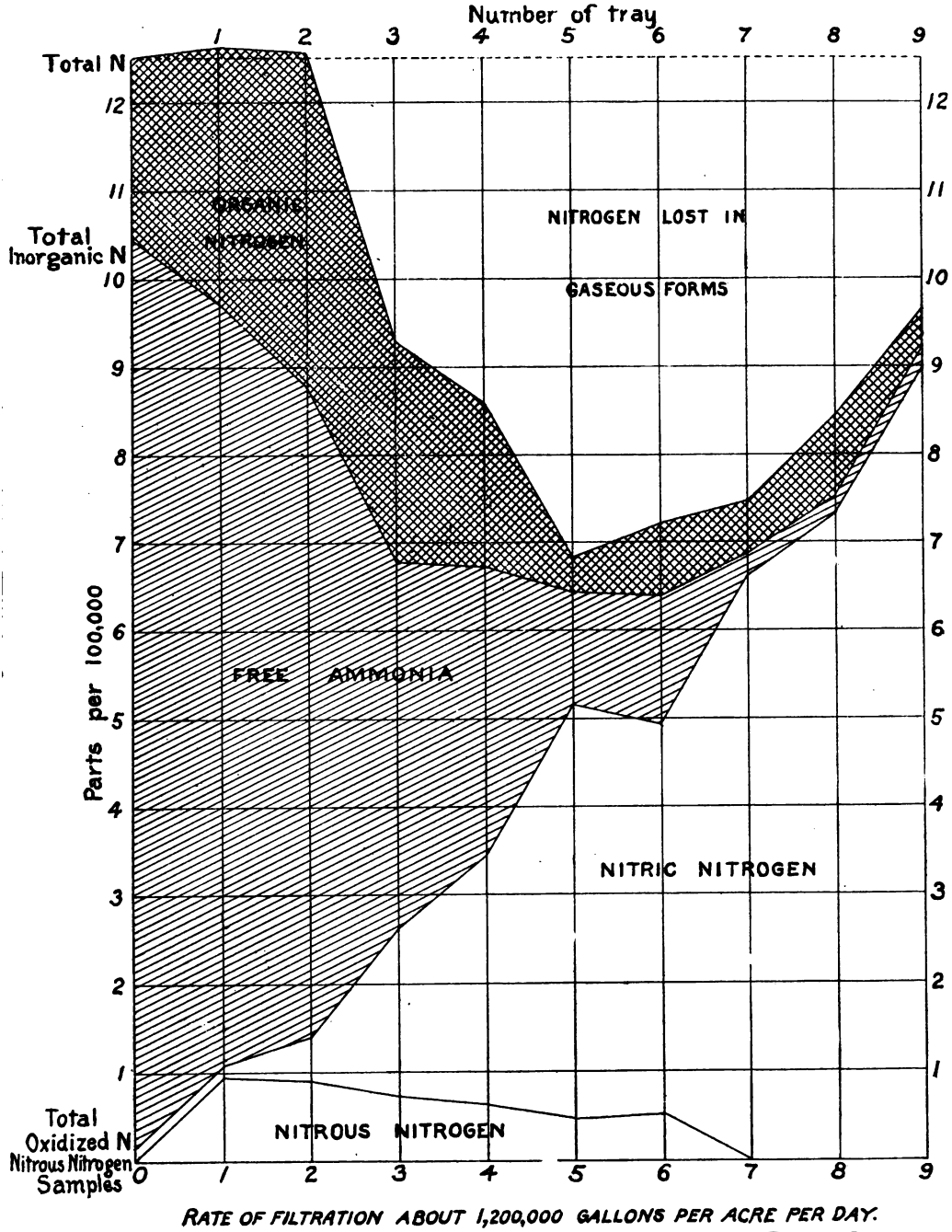
FIG. 4

RESULTS OF ANALYSES OF SEPTIC SEWAGE AND EFFLUENT FROM THE VARIOUS TRAYS OF THE SCOTT-MONCRIEFF PLANT AT ASHTEAD, ENGLAND, OBTAINED THROUGH DR. SAMUEL RIDEAL. JANUARY 25, 1898



RATE OF FILTRATION ABOUT 1,200,000 GALLONS PER ACRE PER DAY.

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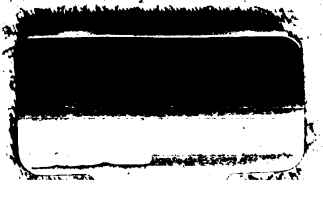

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